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# SEMIANNUAL REPORT TO CONGRESS

JANUARY 1 — JUNE 30, 1969

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



TO THE CONGRESS OF THE UNITED STATES:

Transmitted herewith is the Twenty-first Semiannual Report  
of the National Aeronautics and Space Administration.

THE WHITE HOUSE,  
JULY, 1970.

*Richard Nixon*

Twenty-first  
**SEMIANNUAL  
REPORT TO  
CONGRESS**

JANUARY 1 - JUNE 30, 1969



**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**  
**WASHINGTON, D. C. 20546**

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THE PRESIDENT  
*The White House*

May 27, 1970

DEAR MR. PRESIDENT:

I submit this Twenty-First Semiannual Report of the National Aeronautics and Space Administration to you for transmittal to Congress in accordance with section 206(a) of the National Aeronautics and Space Act of 1958. It reports on activities which took place between January 1 and June 30, 1969.

During this time, the Nation's space program moved forward on schedule. Apollo 9 and 10 demonstrated the ability of the manned Lunar Module to operate in earth and lunar orbit and its readiness to attempt the lunar landing. Unmanned observatory and explorer class satellites carried on scientific studies of the regions surrounding the Earth, the Moon, and the Sun; a Biosatellite carrying complex biological science experiment was orbited; and sophisticated weather satellites and advanced commercial communications spacecraft became operational. Advanced research projects expanded knowledge of space flight and spacecraft engineering as well as of aeronautics. In the latter area, important progress in avionics was achieved with studies of air traffic control, collision avoidance, and the use of satellites for aviation navigation and communication.

While the report was being prepared, the Apollo 11 and 12 astronauts landed on the moon and explored its surface. These successful missions confirmed the value of a systematic approach to problem solving in the manned space flight program, demonstrated the technological leadership of the United States in planning and managing this unprecedented enterprise, and offered hope that these same skills can be extended to benefit people here on earth.

Respectfully yours,

T. O. PAINE,  
*Administrator.*



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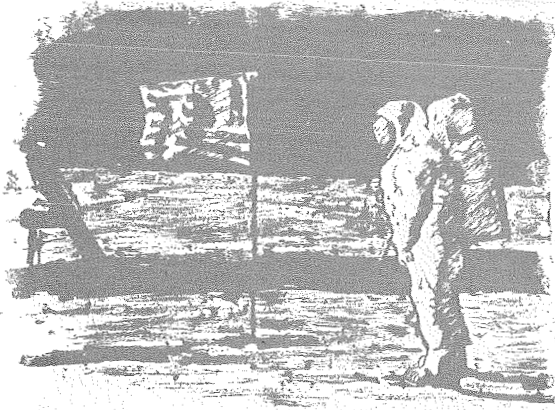
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# ACTIVITIES & ACCOMPLISHMENTS







## MANNED SPACE FLIGHT

In the first six months of 1969, the nation's manned space flight program moved progressively closer to the objective of the decade, a manned lunar landing and safe return to earth. At the same time, planning was accelerated for space flight programs of the next decade.

A dress rehearsal for the actual moon landing was accomplished in May, when the three Apollo 10 crewmen flew to lunar orbit, and two of them descended to within 9 miles of the lunar surface in the lunar module, while the command module remained in lunar parking orbit. Final preparations were in progress for the actual lunar landing which will be attempted in the Apollo 11 mission scheduled for July.

Development continued for the Apollo Applications Program which will conduct scientific, technical, and medical activities in earth-orbital flight beginning in 1972. Task forces for development of a space station and a reusable space shuttle were established and preliminary study work was begun.

### APOLLO PROGRAM

Momentum continued to build in the Apollo Program as two highly successful preliminary missions were flown in preparation for the first lunar landing mission. In March, Apollo 9 provided the first manned flight test of the lunar module in earth orbit; in May, Apollo 10 exercised the lunar module in a simulated lunar landing during man's second journey to the moon. The two missions were the basis for high confidence that Apollo 11, which was in preparation during the period, would succeed.

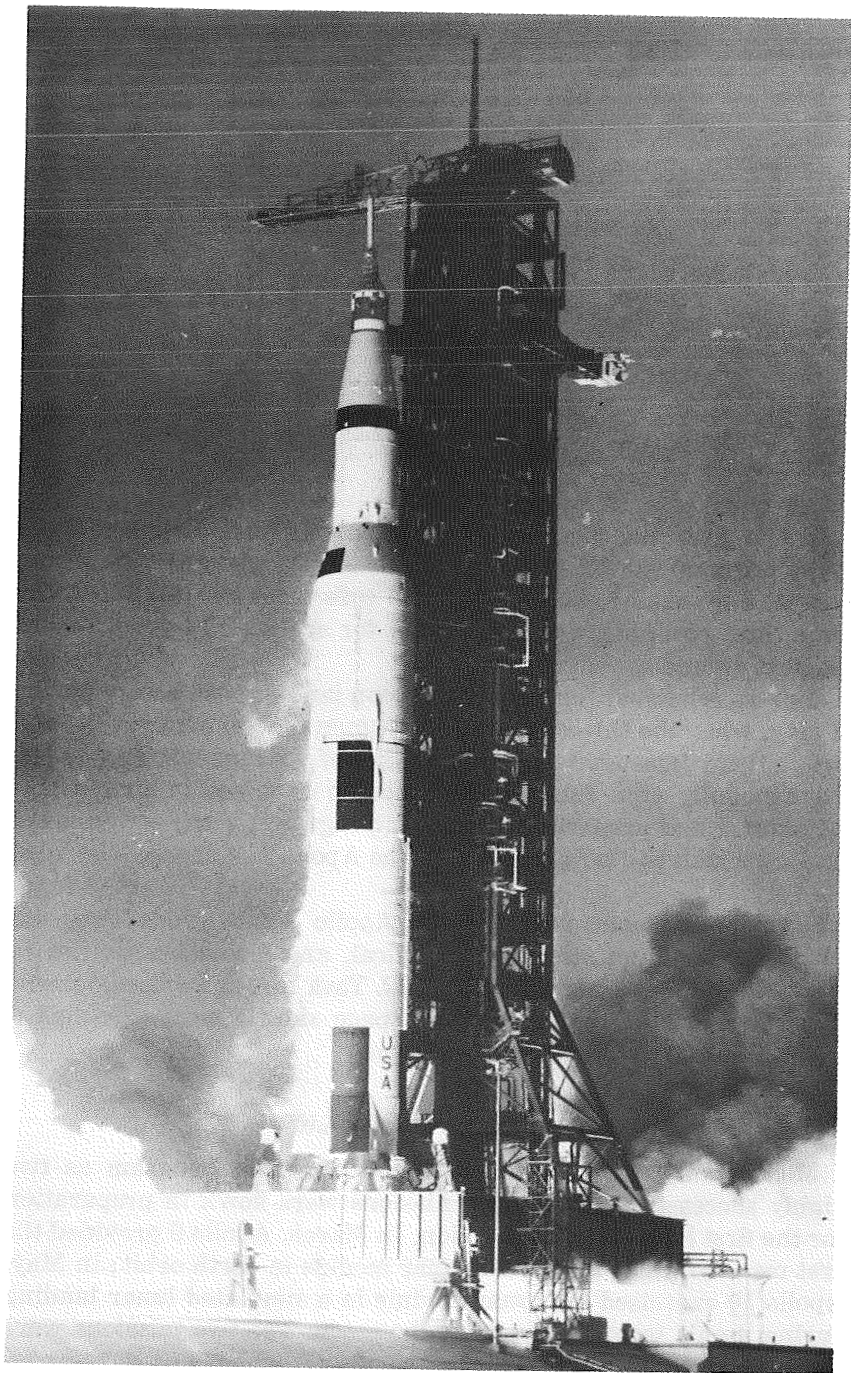


Fig. 1-1. Apollo 9 launch.

### Apollo 9 Mission

The Apollo 9 space vehicle was launched from the Kennedy Space Center (KSC) at 11:00 a.m., EST on March 3. This earth orbit mission lasted ten days, during which the astronauts conducted critical maneuvers involving the Lunar Module (LM) and the Command and Service Module (CSM). Simulations of the lunar mission were executed flawlessly and splashdown occurred in the Atlantic on March 13. (Fig. 1-1)

The primary objective of the Apollo 9 mission, to evaluate the performance of the complete Apollo system in a manned earth orbit flight, was achieved. The LM, flown for the first time with men aboard, operated precisely and thus completed the certification of major hardware required before attempting a lunar landing.

The Apollo 9 launch was originally scheduled for February 28, and the countdown was proceeding satisfactorily until a virus respiratory infection affecting all crew members caused it to be rescheduled to March 3. The three-day postponement permitted the astronauts to recover from their mild illness.

All launch vehicle stages burned within nominal limits, inserting the S-IVB/spacecraft combination into an orbit of 117.7 by 118.8 miles (118.5 by 118.5 planned). With orbit achieved, the Apollo 9 crew—Spacecraft Commander (CDR) James A. McDivitt, Command Module Pilot (CMP) David R. Scott, and Lunar Module Pilot (LMP) Russell L. Schweickart—made preparations for the six periods of activity into which the 10-day mission was divided. The schedule for the first half of the flight assigned more work to the crew than on any previous mission. The heavy initial workload was designed to make certain that the major objectives would be accomplished even if it were necessary to terminate the mission early.

*First Period.*—After achieving orbit, the CSM was separated, transposed, and docked with the LM. The CSM/LM combination was then separated from the S-IVB third stage of the booster. Following this maneuver, the astronauts conducted the first unmanned restart (second burn) of the S-IVB stage, placing it in an orbit of 1,918 by 129 miles. Next, the first firing of the Service Propulsion System (SPS), a 5.1 second burn, placed the spacecraft in a 145 by 125 mile orbit.

(In a lunar mission, the spacecraft and the S-IVB would remain attached and restart of the S-IVB would propel the spacecraft out of earth orbit into a trajectory to the moon. Also, on the lunar flight, the service module engine would slow the spacecraft into an

orbit about the Moon and, later, boost the spacecraft out of lunar orbit into a trajectory back to Earth.)

A third burn of the S-IVB placed it in solar orbit as planned.

*Second Period.*—Three docked SPS maneuvers were performed to put the spacecraft in a position for optimum lighting during rendezvous maneuvers scheduled for the fifth period. The third SPS burn in this period placed the spacecraft in a 312 by 126 mile orbit. Also, the three SPS burns reduced the weight of the CSM by consuming propellant, and thus gave the spacecraft a quick response capability with use of the small reaction control thrusters for rescue of the LM in case of emergency during the rendezvous maneuvers.

*Third period.*—This activity period occurred on the third day of the flight. Astronauts McDivitt and Schweickart crawled from the CM to the LM through the 32-inch-diameter tunnel—the core of the docking mechanism—to begin the checkout of the LM. The spacecraft was pressurized, its power turned on, and its various systems were tested. Then, the LM's Descent Propulsion System (DPS) engine was fired for the first time. The descent engine was throttled over a wide range of power settings, manually and by

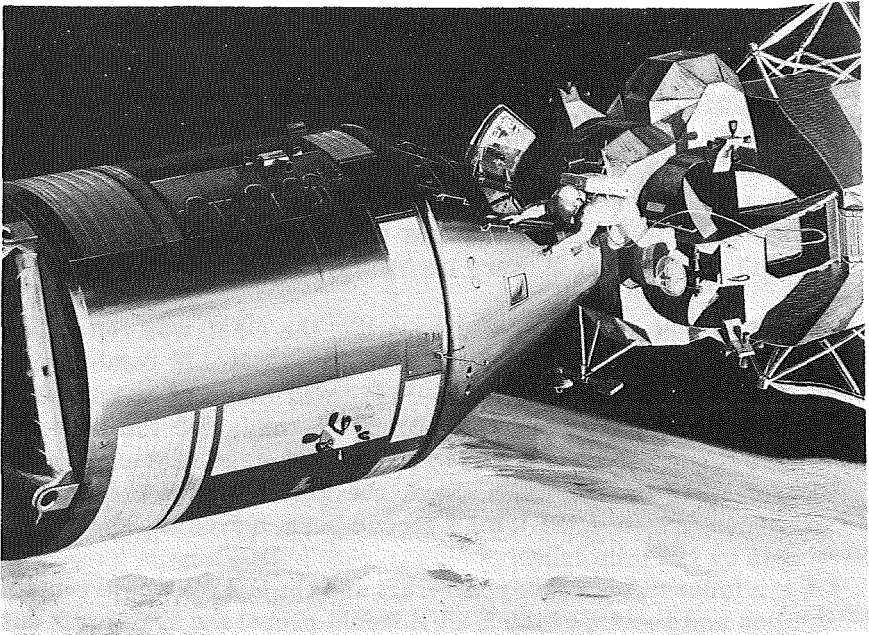


Fig. 1-2. Artist's concept of astronaut emerging from LM and moving to docked CM.

autopilot. With the test schedule completed, the vehicle systems were powered down and the two astronauts crawled back into the CM. A fifth burn of the SPS circularized the orbit of 148.7 by 142.5 miles as the base orbit for the rendezvous maneuvers. A feature of the day was a 5-minute live broadcast to earth during which the astronauts trained the TV camera on the instrument displays, other features of the LM interior, and on themselves.

*Fourth Period.*—Schweickart's quick recovery from several attacks of nausea permitted rescheduling of the walk in space originally scheduled for this period. Because of the illness, however, the walk was modified by reducing its duration from two hours to 38 minutes, and by curtailing Schweickart's activities. In preparation for the extra-vehicular activity (EVA), McDivitt and Schweickart returned to the LM, turned on all systems, and donned the portable life support equipment. Then the hatches of both spacecraft were opened and Schweickart eased out of the LM hatch to begin his EVA, the first space walk for a U.S. astronaut in 2 years. He took photographs, retrieved some thermal samples from the exterior of the LM, and experimented with the handrails—although he did not make the hand-over-hand trip from the LM to the CM that was planned initially. Schweickart reported the handrails were excellent for maintaining position. (Fig. 1-2)

During these activities, he wore a backpack which provided his communications, supplied him with oxygen, and circulated water through the suit to keep him cool. (Fig. 1-3) This was the first trial of a backpack of this kind in space, and the unit worked well. Schweickart's only tie with the LM was a nylon cord to keep him from drifting off into space. Meanwhile, CMP Scott retrieved thermal samples from the CM exterior by reaching through the open hatch of the CM.

After Schweickart reentered the LM, both spacecraft were repressurized, and a second and final 10-minute TV show was telecast from inside the LM. Both voice and pictures were good. Following the telecast, McDivitt and Schweickart powered down the LM and returned to the CM.

*Fifth Period.*—For the LM and its crew, and for the Apollo Program, March 7th was the crucial day—the first test of the LM in earth orbit in which all the lunar mission maneuvers except the actual landing would be performed. Activities began with Astronauts McDivitt and Schweickart returning to the LM, activating its systems, and performing a separation maneuver in which the LM pulled away from the CSM. (Fig. 1-4) After the LM rolled on its axis so CMP Scott could make a visual inspection, a burn of its



Fig. 1-3. Schweickart wearing backpack during EVA.

descent propulsion system (DPS) positioned the LM 3 miles from the CSM in an equal, but different, orbit. This maneuver had a built-in safety factor. Because of the nature of the orbits, the LM and CSM would come very close to each other twice during a single orbit—close enough for the CSM to recover the LM in the event of a malfunction or failure.

The last series of maneuvers began when the final burn of the DPS inserted the LM into an orbit which positioned it approximately 115 miles behind the CSM. At this distance the two spacecraft did not have visual contact with one another. After the ascent stage of the LM separated from the descent stage, burns of the reaction control system (RCS) and the ascent propulsion system (APS) together with guidance from radar and other instruments were used to maneuver the ascent stage to a flawless docking with the CSM.

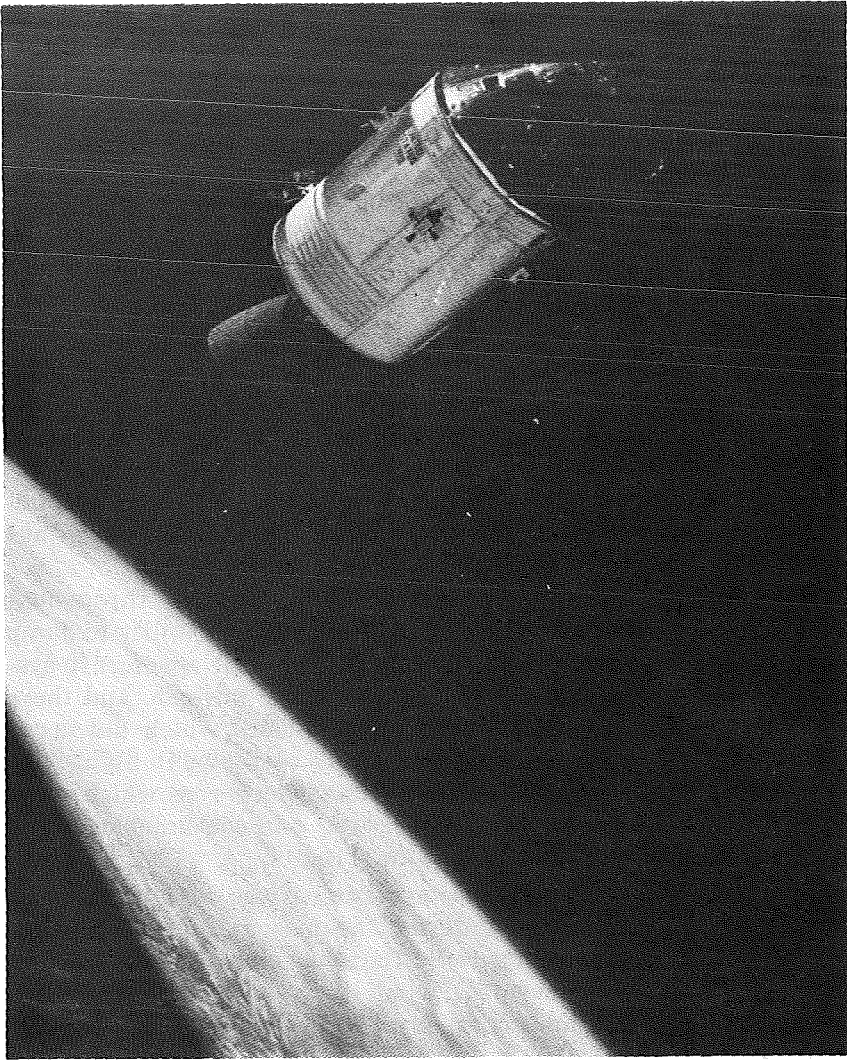


Fig. 1-4. The CSM photographed from LM.

McDivitt and Schweickart shut down the LM and crawled back to rejoin Scott in the CSM. The LM was separated from the CSM and a final burn of the APS sent the ascent stage into an orbit approximately 4,600 miles high.

*Sixth Period.*—The remainder of the flight was devoted primarily to landmark tracking and experiments in earth photography. Also during this period, two SPS orbit shaping burns were exe-

cuted to raise the apogee and lower the perigee. The spacecraft carried four 70-mm cameras that took pictures in black and white, infrared, and color. The earth resources multispectral photography experiment conducted with these cameras provided extensive coverage over southern United States and included passes over Mexico, Brazil, and Africa. (Fig. 1-5)

The astronauts made a number of daylight star sightings, landmark sightings, and star sextant sightings. The inertial guidance system was aligned with a sighting on the planet Jupiter, the Pegasus II satellite was sighted at a range of approximately 1,000 miles, and the astronauts sighted objects with the crewman optical alignment sight. On the whole, their success seemed to confirm the thesis that the acuity of the human eye is increased in space.

*Results.*—All primary objectives for this mission were achieved, and all launch vehicle objectives were attained. The LM, flown for the first time with men aboard, operated with a precision matching that of the previously validated CSM. The LM's performance thus completed certification of major lunar mission hardware.

All launch vehicle systems performed satisfactorily throughout their expected lifetimes with the exception of the inability to dump propellants following the third S-IVB burn. All spacecraft systems functioned satisfactorily throughout the mission, and there were no major anomalies. Minor discrepancies which did occur were primarily procedural and either were corrected in flight with no mission impact or involved instrumentation errors which could be checked by other means. Temperatures and consumables usage rates remained generally within normal limits.

The flexibility of Apollo mission planning was demonstrated by changing the splashdown site during the mission. Splashdown was originally planned for southwest of Bermuda on revolution 151, but because of predicted marginal wind and sea conditions, it was moved to a location approximately 600 miles east of Cuba, and deferred to revolution 152.

Other Apollo 9 achievements included the fourth Saturn V on-time launch; the largest payload ever placed in orbit; the first demonstration of the second restart of the S-IVB while in orbit; the first CSM-active dock; the first LM-active rendezvous and dock; the first in-flight depressurization and hatch opening of LM and CM; the first Apollo space walk; the first intervehicular transfer of astronauts in shirt sleeve environment between the docked vehicles; the first operational test of the portable life support system to be used for lunar EVA; the first docked SPS burns with CSM guidance and docked DPS burns with LM guidance; success-

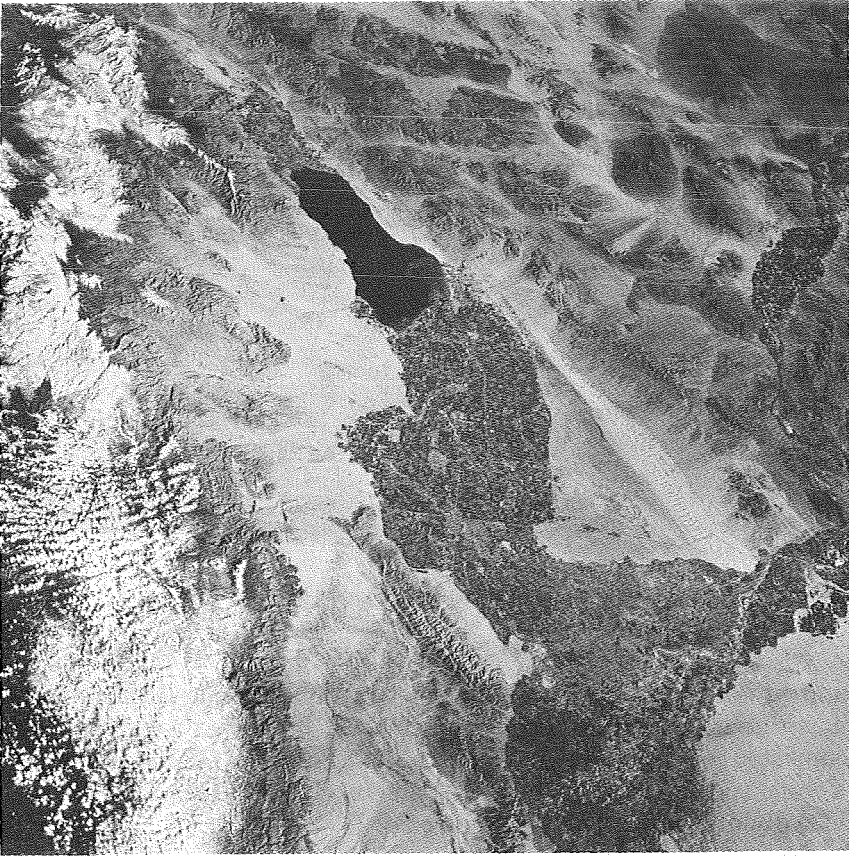


Fig. 1-5. Apollo 9 photo of Mexico, California, Arizona, Nevada, Salton Sea, and Colorado River.

ful demonstration of multiple restarts on SPS, DPS, APS, CM RCS and LM RCS; and the first time one spacecraft has been set-up from another spacecraft for an unmanned propulsion system burn.

#### Apollo 10

The Apollo 10 space vehicle was launched May 18 from Cape Kennedy on an eight-day lunar orbit mission. The Apollo spacecraft was operated around the moon for the first time in a dress rehearsal simulation of the lunar landing mission. The lunar module, making its second manned flight, descended to within nine miles of the lunar surface. The crew took photographs of the lunar surface, provided a running commentary on their observations,

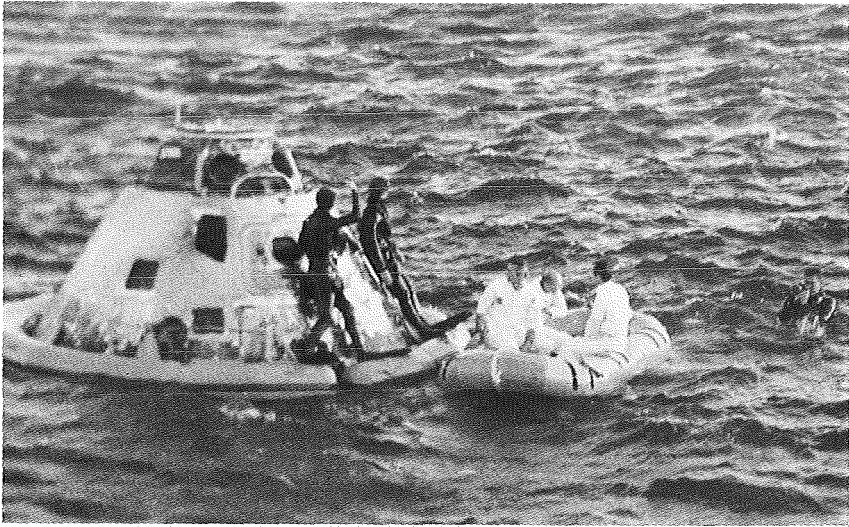


Fig. 1-6. Apollo 10 spacecraft after splashdown.

and subsequently made rendezvous with the orbiting CSM. Splashdown occurred in the mid Pacific on May 26. (Fig. 1-6) The crew consisted of Astronauts Thomas P. Stafford (CDR), John W. Young (CMP), and Eugene A. Cernan (LMP). This mission was also divided into six activity periods.

*First Period.*—The launch of Apollo 10 at 12:49 p.m. on May 18 marked the fifth successive on-time launch of a Saturn V. All launch vehicle stages performed satisfactorily, inserting the S-IVB/spacecraft combination into a nominal earth parking orbit of 118 by 115 miles. Following two earth orbits during which the crew conducted a thorough checkout of the CSM systems, the S-IVB was ignited, propelling the spacecraft on a trajectory toward the moon. Shortly after termination of the S-IVB burn, the CSM separated from the S-IVB/LM combination, turned 180 degrees, and docked with the LM. Subsequently, the spacecraft combination was ejected from the third stage (S-IVB) by spring devices at the four LM landing gear “knee” points. The service propulsion system of the CSM was ignited for 2.5 seconds to move the spacecraft to a safe distance from the S-IVB during the “sling-shot” maneuver which was performed successfully. (In this maneuver, the S-IVB is propelled on a trajectory passing behind the moon’s trailing edge and on into solar orbit.) During this period,

excellent quality color television coverage of the spacecraft docking sequences was seen on worldwide commercial television.

*Second Period.*—Major activities were a midcourse correction, two lunar orbit insertion burns, and initial activation of the LM. The near perfect performance of the spacecraft made it possible to cancel the first scheduled midcourse correction maneuver, and only slight adjustments were needed during the second scheduled midcourse correction maneuver. Following it, all parameters appeared nominal and the third and fourth midcourse correction maneuvers were not required. The spacecraft was captured by the moon's gravitational field at a distance of approximately 39,127 miles from the moon and was pulled into lunar orbit.

During its first orbit, when the spacecraft reached a point directly opposite the earth on the far side of the moon, the SPS engine was ignited, decelerating the spacecraft and inserting it into an elliptical orbit of 196 by 69 miles (almost exactly that planned). Two orbits later, a second lunar orbit insertion maneuver circularized the orbit to 71 by 68 miles (again almost precisely as planned).

While in their first lunar orbit, the crewmen began vivid descriptions of the lunar features. (Fig. 1-7) Astronaut Stafford first commented that they were moving out of the highlands into the mare area—the so-called dry seas. He reported a “couple of real good volcanoes,” an observation of considerable interest to astronomers because of the still unresolved controversy, at the time, as to whether the moon had seen volcanic action. Astronaut Young described the volcanoes as “. . . all white on the outside but definitely black inside.”

The first landmark the crew spotted was the Sea of Crisis, bathed in lunar sunrise. Young observed that it really stood out and that he had no trouble recognizing it. Stafford said the sides of the ridges crossing the mare floor went “straight down just like the Canyon Diablo in New Mexico.” The crew found the “dark” area of the moon surprisingly well lighted by earth shine and had no trouble picking out landmarks. Cernan commented that the side away from the earth was “lit up like a Christmas tree,” and Stafford found the details “phenomenal.” A 29-minute TV transmission showed the lunar surface in color pictures of excellent quality. In preparation for the LM activities of the next period, LMP Cernan crawled from the CSM through the tunnel to the LM where he activated the LM system and performed some communication tests before returning to the CSM.



Fig. 1-7. Moon photographed from Apollo 10.

*Third Period.*—This day was filled with activities. Astronauts Stafford and Cernan performed all the maneuvers required to separate the LM from the CSM, flew the LM independently for 8 hours, descended to within eight miles of the lunar surface (while operating the landing radar, cameras, and other equipment), ascended, made rendezvous, and finally docked with the CSM. (Fig. 1-8)

The day began with Stafford and Cernan crawling through the tunnel to the LM, activating the systems, and checking them out. Then a problem arose. Inability to vent the tunnel between the LM and the CSM did not allow the required pressure differential to be maintained between the command module cabin and the tunnel. This in turn permitted the LM to move about  $3\frac{1}{2}$  degrees out of alignment with the CSM in its docked position. Ground control advised the crew not to undock if the angle exceeded 7 degrees; it was feared that if the angle became larger than that, the locking latches in the docking collar would be damaged and the LM, on its

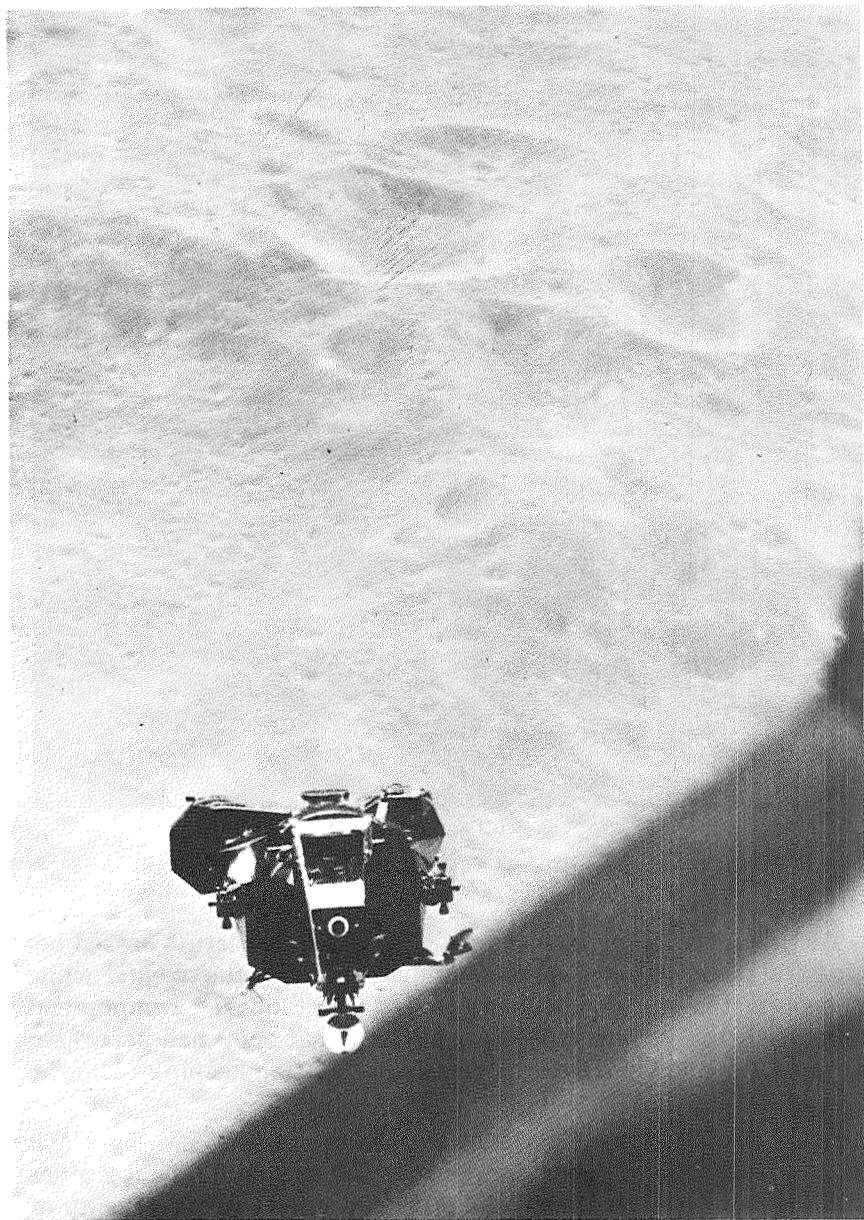


Fig. 1-8. Photo of LM, taken from CSM.

return, would not be able to make a secure hook-up with the CSM, making it difficult for the astronauts to return to the CSM. (Fig. 1-9)

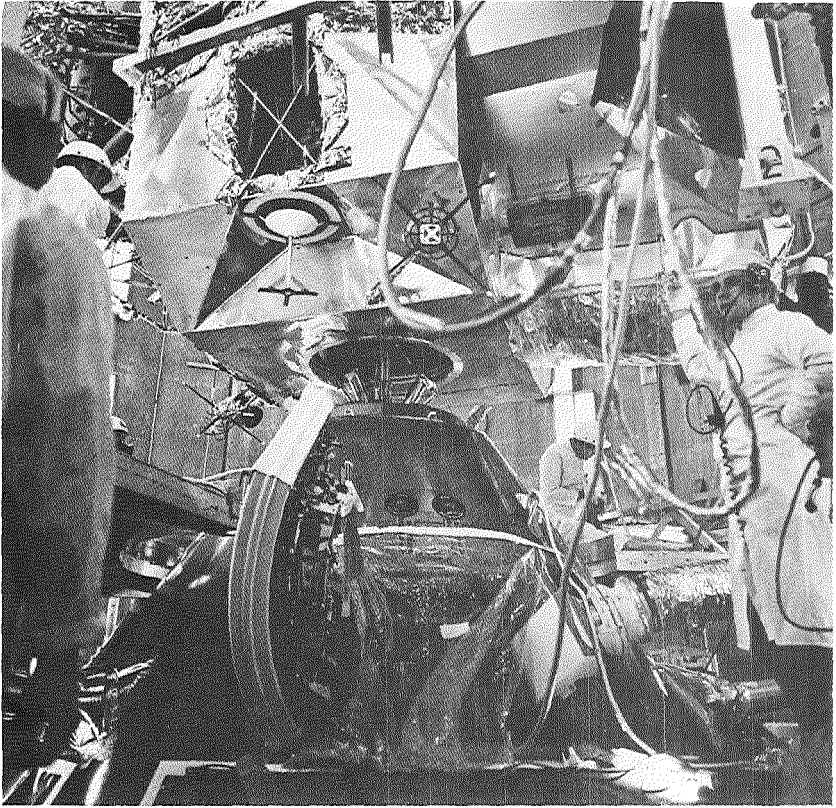


Fig. 1-9. Locking latches and docking Collar for joining CSM and LM.

As this instruction was acknowledged, the spacecraft passed behind the moon and lost all communications with the ground while it was on the far side. When the LM reestablished communications with the ground, the crew advised that they had separated successfully and were flying formation—"station keeping" some 50 feet apart.

Following a thorough visual inspection of the LM by CMP Young, Stafford and Cernan moved the LM to a point about 2 miles from the CTM. Then, firing the DPS and reducing the velocity of the LM, they descended to within 10 miles of the lunar surface at a point about 15 degrees from the site where the Apollo 11 will land. It is at this point that the powered descent to the lunar landing will be initiated in the Apollo 11 mission.

During this low altitude pass over the lunar landing site, the LM

landing radar was tested, numerous photographs were taken of the lunar surface, and the astronauts provided a continuous commentary of their observations. (Fig. 1-10)

About ten minutes after the pass over landing site 2, the DPS was ignited to position the LM in proper relation to the CSM for an insertion maneuver simulating ascent of Apollo 11 from the lunar surface. Just before the insertion maneuver, the LM descent stage was jettisoned, using the abort guidance system. However, the switch for the control mode was inadvertently set on the "Automatic" mode instead of the "Attitude Hold" mode, and the LM began to gyrate wildly. Astronaut Stafford took manual control of the LM, halted the gyrating, and reestablished proper attitude. The gyrations of the LM were caused by the guidance system which, operating perfectly in the "Automatic" mode, commanded the LM to roll as its rendezvous radar antenna searched for the CSM.

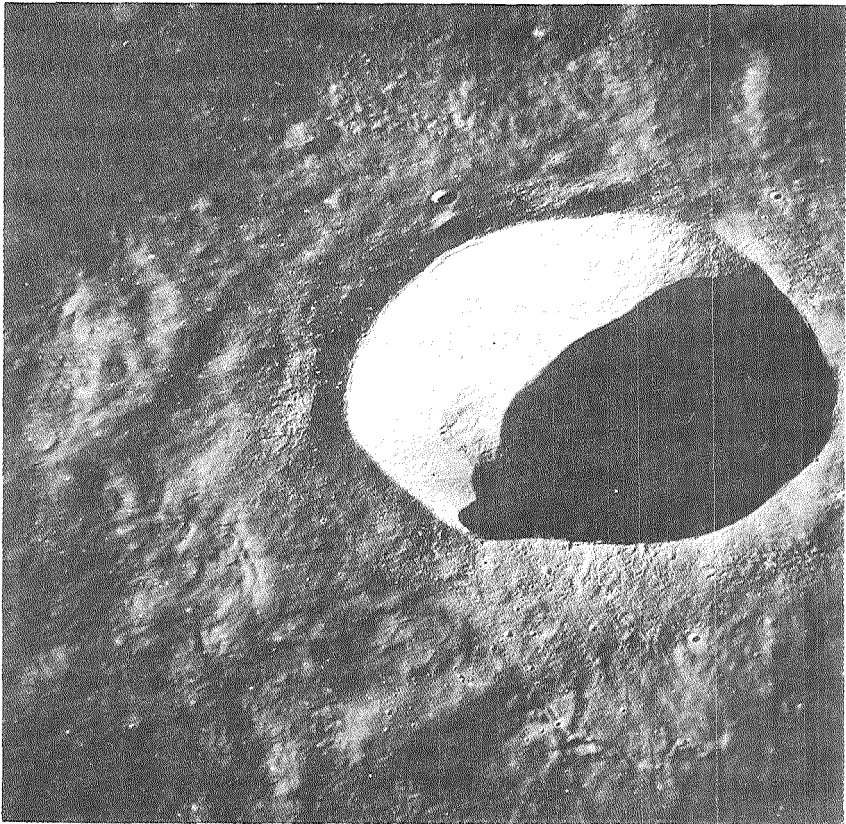


Fig. 1-10. Lunar crater Schmidt photographed from Apollo 10 LM.

Following separation from the descent stage, the APS was fixed at the lowest point of the orbit to perform an insertion maneuver which was equivalent to a standard LM insertion orbit of a lunar landing mission. Using the RCS, the astronauts performed three separate maneuvers, bringing the LM to within docking range of the CSM. With the LM passive, the RCS of the CSM was used in a smooth and expeditious docking of the spacecraft. After the LM crew transferred to the CSM, bringing with them exposed film packets and two cameras, the CSM was separated from the LM.

*Fourth Period.*—About one revolution after docking, and on command from the Manned Space Flight Network, the LM APS was ignited to propel the LM ascent stage toward a solar orbit, primarily to preclude future contact with the spacecraft. During the remaining period of lunar orbital operation, the astronauts took 18 landmark sightings, made extensive stereo strip and oblique photographs, and also observed the LM descent stage on several occasions. Two scheduled TV periods were deleted because of crew fatigue.

While on the far side of the moon during the thirty-first orbit, the crew fired the SPS to gain the velocity needed to escape from lunar orbit on a transearth trajectory. So exact was the burn that the speed achieved was only .04 miles per hour less than planned, and the first two transearth midcourse corrections scheduled for the next period of activity were cancelled.

*Fifth Period.*—The astronauts took star lunar landmark navigation sightings and star-earth horizon navigation sightings, conducted the CSM S-band high gain reflectivity test, and made five television broadcasts.

*Sixth Period.*—Activities included reentry, splashdown, and recovery, all of which were approximately as planned and on schedule. Splashdown occurred about 3 miles from the prime recovery ship, the USS *Princeton*.

*Results.*—All primary mission objectives were achieved. All launch vehicles and spacecraft systems performed satisfactorily during the mission, and the few minor discrepancies that did occur were readily corrected. Temperatures and consumables usage rates remained generally within normal limits for the entire mission.

Flight crew performance was outstanding. All three crew members remained in excellent health throughout the mission. They did extensive surface photography and landmark tracking, providing valuable data for planning future lunar landing missions. Their prevailing good spirits were continually evident as they took time

from their busy schedule to share their voyage with the world through 19 color television transmissions totalling almost six hours.

The LM demonstrated convincingly its operating capabilities in cislunar space and validated the ascent propulsion system and the descent propulsion system, which are vital to the lunar landing mission in the moon's environment. In two circuits of the moon, the landing radar received a thorough checkout. It was used to check the lunar surface reflectivity characteristics, providing valuable data for mission planning and crew training for the Apollo 11 mission. The rendezvous radar was tested at a maximum range of approximately 403 miles.

The Apollo 10 mission provided additional operational experience for the crew and for mission support facilities. It demonstrated (in the maneuver which separated the ascent stage from the descent stage of the LM) that men can overcome problems in space and save a mission where instruments alone might fail. Another major achievement was the determination that the preferred landing site is smooth, but that the Apollo 11 LM crew will have to be accurate in touching down at the right spot.

In addition, space experience and data gathered from navigating around the moon increased knowledge of the lunar gravitational effect and enabled NASA to further refine its Manned Space Flight Network tracking techniques.

#### Apollo 11

The primary objective of the Apollo 11 mission is to make a manned landing on the moon and return to earth safely. Planned lunar surface activities will include a lunar walk by the astronauts of not more than three hours; collection of lunar soil samples; assessment of astronaut capabilities and limitations; and deployment of experiment packages including a laser reflector for precise measurements of earth-lunar distances, instruments for measuring seismic activities, and instruments for measuring solar wind composition.

In mid-January flight hardware for Apollo 11 began arriving at Kennedy Space Center with delivery of the LM and the CSM. Both were subjected to unmanned and manned tests with the prime mission crew in the altitude chamber at KSC. The tests were conducted to verify spacecraft systems and the astronaut life support systems under conditions simulating the vacuum of space. After the tests, the LM and CSM were mated in preparation for transfer to the Vehicle Assembly Building (VAB).

The launch vehicle flight hardware began arriving at KSC in late January, and in early March the three stages and the instrument unit were erected on the mobile launcher in the VAB. Tests were conducted on individual systems of each of the stages, and on the overall launch vehicle before the spacecraft was erected atop the vehicle in mid-April. Tests were conducted to verify integration of the spacecraft with the launch vehicle and to confirm the interfacing between the space vehicle and the ground and electrical support equipment.

After successful completion of these tests and electrical mating of the space vehicle, Apollo 11 was rolled out to Pad A on May 20 to begin final preparations for launch (scheduled for July 16). (Fig. 1-11) Following a flight readiness test on June 6, a successful flight readiness review was conducted to verify the readiness of all hardware, software, and operational elements to support the mission. On June 30 a countdown demonstration test with all propellants loaded, simulating the final launch countdown, was progressing satisfactorily with completion scheduled for July 2.

Modifications which were necessary to resolve anomalies from previous Apollo flights were incorporated in Apollo 11.

In June, a 7-day simulation was completed successfully in the lunar receiving laboratory at the Manned Spacecraft Center where the astronauts, spacecraft, and lunar samples will be isolated after splashdown and undergo quarantine procedures to minimize the possibility of contamination. The simulation covered processing of the lunar samples, operation of the mobile quarantine facility and crew reception area, and biolaboratory activities. Action was taken to overcome the procedural and equipment difficulties encountered in the vacuum laboratory and to complete the remaining outstanding work to meet the schedule.

#### Apollo 12

Apollo 12 will be the second Apollo lunar landing and the first mission conducted in support of the lunar exploration phase of the Apollo Program. Primary objectives are to make an inspection, survey, and sampling of the lunar surface in a mare area; to deploy the first full Apollo Lunar Surface Experiments Package (ALSEP); to develop techniques for a point landing capability; and to develop man's capability to work in the lunar environment. The Apollo 12 space vehicle will be configured with the SA-507 launch vehicle, CSM-108 command and service module, and the LM-6 lunar module.

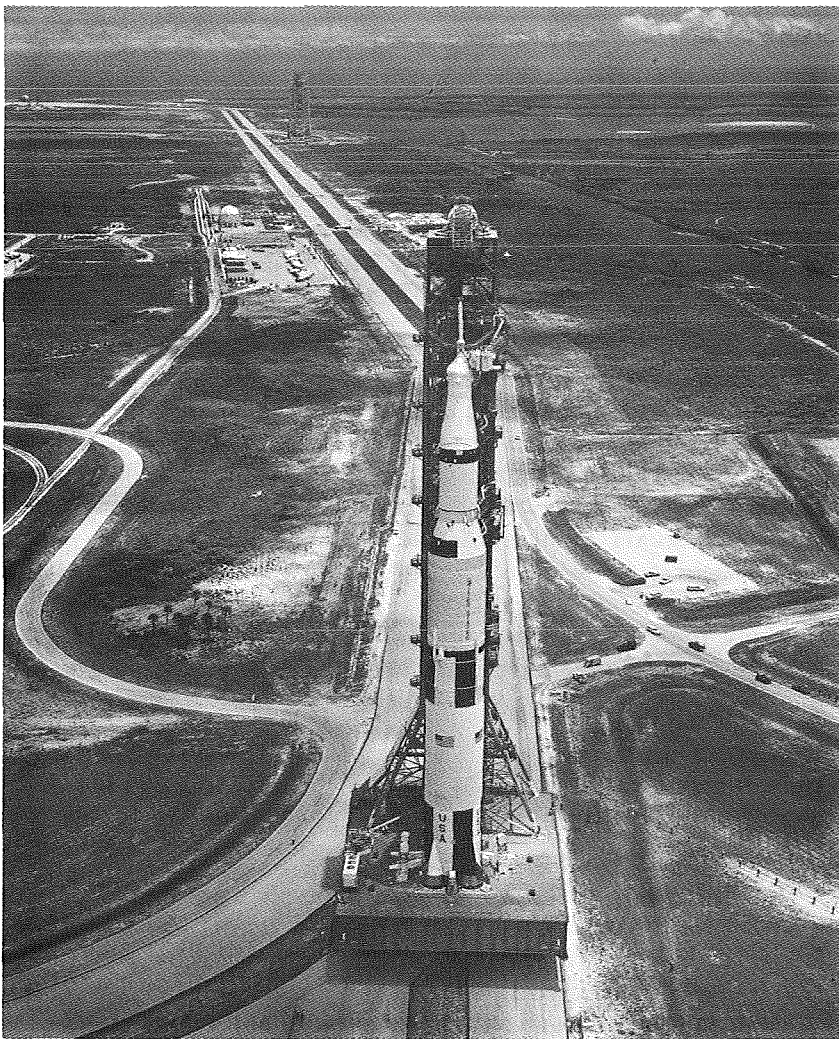


Fig. 1-11. Roll-out of Apollo 11.

In mid-March, flight hardware for Apollo 12 began arriving at the KSC with the delivery of the LM and the CSM. Subsystems and combined systems tests conducted on both were completed in early May. Unmanned and manned tests with both prime and backup astronaut crews were conducted in the altitude chamber at KSC with the CSM and LM to verify operation of spacecraft systems and the astronauts life support systems under conditions sim-

ulating the vacuum of space. Following the completion of these tests in mid-June, the LM and CSM were mated in preparation for transfer to the VAB.

The launch vehicle flight hardware began arriving at KSC in mid-March, and in late May the three stages and the instrument unit were erected on the mobile launcher in the VAB. Tests were conducted on individual systems on each of the stages, and on the overall launch vehicle in readiness for spacecraft erection. The spacecraft was transported to the VAB on June 30, and spacecraft erection was in progress with completion scheduled for July 1.

#### Development Testing

The successful Apollo 9 and Apollo 10 missions mark the completion of all development flight testing required for a lunar landing mission. Ground testing during the first half of 1969 was being done to complete the remaining tests to certify spacecraft hardware for manned space flight, and to resolve performance anomalies which occurred during Apollo 8, 9, and 10 missions.

*Command and Service Module.*—Development tests for the CSM were conducted, structural tests to qualify the probe and drogue assembly for CSM/LM docking before the Apollo 9 mission were completed, and the command module chute loads test was carried out.

The window frames of the Apollo 9 CSM were modified to eliminate the fogging effect encountered during the flights of Apollo 7 and 8. Results of a ten day thermal-vacuum test showed that the new post cure cycles, used on the Apollo 9 CSM window frames, will preclude fogging.

*Lunar Module.*—The LM development tests were conducted, and propulsion tests certifying both the ascent engine and the descent engine for Apollo 10 and Apollo 11 missions were completed.

Tests were conducted to determine plume impingement characteristics of the reaction control system on the lunar module structure during the lunar descent phase. As a result of these tests, plume deflectors were installed on the Apollo 11 LM.

Tests to duplicate the pressure drop in the lunar module descent engine regulator manifold during the Apollo 9 mission confirmed the theory that this condition was caused by air introduced during ground servicing of helium. Accordingly, NASA established a new loading procedure to eliminate the introduction of air during this operation.

In preparation for the Apollo 11 mission, a series of LM drop tests was conducted to study the dynamics of the LM and the performance of subsystems at lunar touchdown descent rates.

*Launch Vehicle.*—Development effort concentrated on investigating and resolving the launch vehicle anomalies which occurred during the Apollo 8 and Apollo 9 missions. The most significant of these was the oscillation of the center engine of the S-II stage on its supporting thrust structure. This is similar to but less severe than the POGO oscillation of all 5 engines experienced on the S-IC-2 stage of Apollo 6.

After a thorough evaluation of the S-II oscillation, engineers proposed to eliminate it by an early center engine cutoff of the Apollo 10 S-II stage (S-II-5). A full duration static test was conducted on the S-II-8 stage at the Mississippi Test Facility (MTF) in April, with an early center engine cutoff simulating the operating condition for the Apollo 10 S-II stage. During this test, the center engine was free of the undesirable oscillations and was not subjected to excessive thermal environment. Based on these favorable test results and a transient loads analysis, an early center engine cutoff was approved for the Apollo 10 S-II stage, and the procedure proved successful on the mission.

Early center engine cutoff has one drawback, however; it reduces the payload capability since the total thrust is reduced during the latter portion of the S-II burn period. An alternate method of damping S-II center engine oscillation, which will not require the early center engine cutoff, uses a pneumatic accumulator in the center engine liquid-oxygen feedline. An accumulator was being installed on the S-II-10 stage for evaluation during static firing in September.

The S-IC-6 and the S-IC-7 were delivered to KSC in February and May, respectively, and the S-IC-8 was delivered in June. The S-IC-9, and S-IC-10 were shipped to MTF for static firing acceptance testing, then returned to Michoud for checkout and preparation for delivery to KSC. Stages S-IC-12 through 15 were in various phases of assembly at the factory during this period.

The S-II-6, S-II-7, and S-II-8 after post static firing checkout and installation of modifications, were delivered to KSC. The S-II-9 and S-II-10 were at MTF for static firing acceptance testing and post firing checkout. Stages S-II-11 through 15 were in various phases of manufacture and assembly.

S-IVB-507 and S-IVB-508 were subjected to test firing checkout and shipped to KSC. S-IVB-509 was removed from storage, subjected to static firing acceptance testing, prepared for shipment to KSC, and placed in storage. S-IVB-510 was shipped to the Sacramento test facility in June for static firing acceptance testing, and

stages S-IVB-511 through 515 were in various phases of fabrication and assembly or modification.

S-IU-507 was checked out, retrofitted, retested, and delivered to KSC in May. Assembly checkout of the S-IU-508 in March and April was followed by retrofitting and retesting. Component assembly of the S-IU-509 was completed in May, and checkout was in progress. Stages S-IU-510 through 512 were in various stages of fabrication and assembly.

*Extravehicular Mobility Unit.*—Thermal vacuum tests were completed with the Apollo 9 crew and the Apollo 11 crew, using the extravehicular mobility unit (EMU). (Fig. 1-12) The EMU consists of the extravehicular suit, oxygen supply, and all other equipment needed to provide life support for a four-hour mission outside the lunar module without replenishing expendables. The equipment operated properly, and the crew was able to function satisfactorily for simulated mission conditions. Tests to qualify improved arm bearings were completed in May. The bearings were incorporated in the extravehicular suit for the Apollo 11 crew to provide increased mobility.

*ALSEP/EASEP.*—Qualification testing of the Early Apollo Scientific Experiment Payload (EASEP) was completed in April. EASEP, for Apollo 11, is a modification of the Apollo Lunar Surface Experiments Package, the full lunar experiment package for Apollo 12 and subsequent Apollo missions. Since so little is known of the endurance and mobility of man in the lunar environment, a primary objective of the Apollo 11 lunar walk will be to evaluate the capabilities and limitations of the astronauts. For this reason EASEP was developed. During an EVA demonstration, the Apollo 12 astronauts deployed the EASEP successfully. In June, the scientific investigators and the Apollo 11 astronauts conducted a successful simulation of the EASEP activities, ranging from the data plans and procedures to the use of facilities. ALSEP I was delivered to KSC and installed in the Apollo 12 spacecraft in June.

#### Lunar Exploration

Each success of the early Apollo missions increased the probability that a lunar landing can be achieved with significantly fewer than 15 Saturn V space vehicles. The number 15 had been established early in the program to provide reasonable assurance that the program objective of a lunar landing would be achieved. Achievement of the lunar landing as early as Apollo 11 would provide the opportunity for exploiting the investment and the

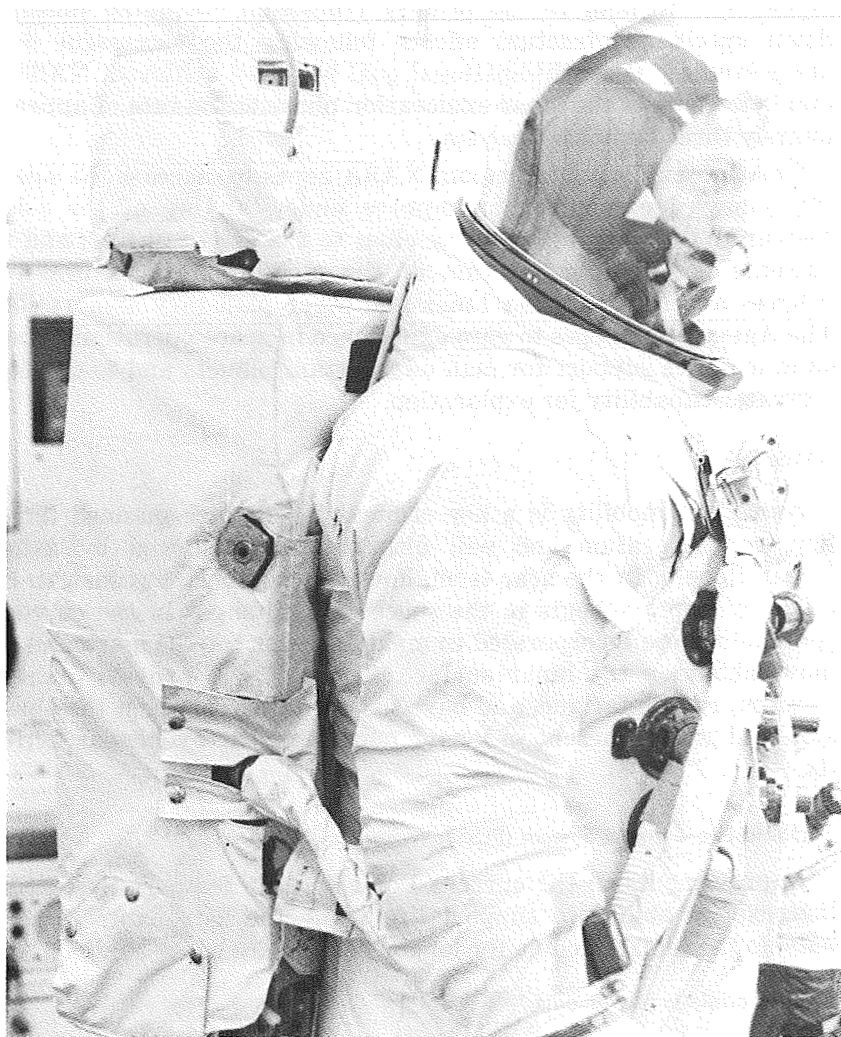


Fig. 1-12. Astronaut wearing extravehicular mobility unit.

capability of the Apollo Program for continued lunar exploration. The remaining Saturn V vehicles and associated spacecraft are well into production and are being delivered to support the planned requirements to achieve the first lunar landing. With an early landing, this hardware could provide the basic system for a significant lunar exploration program.

Recognition of such an opportunity led to comprehensive studies, starting in early 1969, to define this lunar exploration phase of

Apollo and to plan for an orderly transition, including phasing down specific contractual efforts following the successful first lunar landing. Once this national goal has been achieved, NASA's aim is to conduct the lunar exploration phase at the rate of approximately three launches per year.

Through exploring the moon, NASA hopes to increase the scientific knowledge required to improve understanding of the solar system and its origin, including clues to the origin of life; and to evaluate potential exploration of the moon for its natural resources and as a base for lunar and other planetary exploration. The Agency also hopes to gain experience in space operations, such as in logistics support for man on a distant planet; and to develop a greater capability for exploration.

#### Space Suit

Astronaut mobility is a key element in effective manned lunar surface exploration and will ultimately be achieved by using Lunar Rovers. In the near term, however, significant gains can be made by improvements in the space suit. Changes in the current space suit were incorporated to make it easier for the astronaut to move about on the lunar surface. The suit will provide greater comfort, reduce fatigue, and have the durability to resist the abrasion and wear inherent in longer periods of extravehicular activity.

#### Portable Life Support System (PLSS)

Improvements in the current Portable Life Support System to increase its ability to support life while the astronauts remain outside the Lunar Module for longer periods are being studied.

#### Lunar Module Improvements

LM modifications being considered include enlarging the descent propellant tanks to improve LM flexibility in reaching selected sites, and adding water and oxygen tanks, batteries, and crew provisions to increase LM staytime capability from 36 hours to approximately 3 days. The latter would also improve habitability.

#### Lunar Orbital Science

The CSM has a potential for obtaining valuable scientific data while in lunar orbit. Also, the Service Module has an empty bay which can be used to carry the instruments needed for acquiring this scientific data from the lunar surface. A variety of scientific

instruments has been studied over the past few years, with a view to providing scientific capability for the CSM while it is orbiting the moon. These instruments include cameras and other remote sensors which will permit detailed geologic and geochemical study of the interrelationships of surface features on the moon and allow some scientific extrapolation of the data returned from samples and other surface measurements.

In April, 29 possible experiments for CSM lunar orbital science were identified. Ten of these were approved as science candidate experiments. In addition to these experiments, 24 additional proposals were received from the scientific community in response to NASA's "Announcement of Flight Opportunities." These were evaluated by NASA's science committees, and seven were recommended for incorporation in future flights to the moon. The development and procurement of experiments to be flown in Bay 1 of the Service Module have been authorized.

In addition to modifications to Bay 1 of the SM to incorporate the scientific instruments, CSM changes are also required to extend the mission duration from 10.7 to approximately 16 days.

#### *Lunar Mobility Aids*

To expand the lunar exploration capability further, studies of additional mobility aids were being continued. Beyond improved suit mobility, there will be a need for aids to permit the astronauts to visit areas of difficult access but high scientific interest. The major mobility aid under active study is the manned roving vehicle. This vehicle would make possible more far-ranging automated traverses over the lunar surface and would increase the capability for gathering lunar samples and making observation at a wide range of important science locations.

### APOLLO APPLICATIONS

The Apollo Applications Program (AAP) continued hardware and software development activities. The program is designed to capitalize on the Apollo-developed capabilities and resources to accomplish additional scientific, technical, and medical investigations. (Earlier Semiannual Reports discussed the objectives in detail.)\*

The AAP missions remain the same as previously reported. A Saturn I Workshop will be launched unmanned by a Saturn IB. A follow-up launch of a manned Apollo Command and Service Mod-

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\* The AAP was subsequently renamed Skylab. In Skylab, the Workshop and Apollo Telescope Mount will be launched into orbit by the first two stages of a Saturn V.

ule will rendezvous and dock with the S-IVB stage (Workshop) of the first flight. The Workshop is to provide an environment in which man can live and work under controlled conditions for extended periods of time in space beyond that provided by Gemini and Apollo. The 28-day duration of the first mission will be followed by a 56-day revisit mission. The experiments to be conducted on these missions will study man's physiological and psychological responses in the space environment and provide more detailed information on his capabilities for extended flight.

The second dual-launch mission will consist of a manned Saturn IB launch and an unmanned Apollo Telescope Mount (ATM) with its payload of solar instruments. The ATM will permit man to conduct astronomical observations under conditions free from optical interference by the earth's atmosphere, and will provide a platform to demonstrate man's ability to perform scientific experiments in space.

### Management

NASA took a number of actions to promote uniformity in managing the Apollo and Apollo Applications Program requirements. Affected areas of activity included the Reliability and Quality Assurance Offices and Safety. A joint R&QA Program Plan contains guidelines for both programs, providing to the Centers a single set of requirements/guidelines in areas of mutual interest.

A joint audit of MSC Apollo/Apollo Applications Program Reliability, Quality, and Safety was completed in April. This coordinated effort between Apollo and AAP was conducted in a way that would most effectively serve the interests of both programs.

To consolidate AAP technical support activities, a contractor was selected in March to provide technical support to the AAP Headquarters Program Office. The same contractor had previously been selected to provide similar support to the three NASA Centers involved in AAP.

Interest in the area of fire research resulted in AAP's participation in developing a long-range fire research program for NASA's Office of Manned Space Flight.

Studies were conducted to determine whether or not adjustments could be made to the basic AAP to enhance the efficiency of the missions. The considerations leading to this review were prompted by the success of the Apollo Program, 1970 funding limitations, and the AAP interface with Manned Space Flight planning for 1971 and beyond.

The plan considered the most logical would call for launching the first orbital workshop in 1972, using the first two stages of the Saturn V launch vehicle. By using these two stages, NASA could outfit the workshop on the ground. It could then launch the workshop into a 253 mile circular orbit with the ATM attached, thus replacing two Saturn IB launches.

The Saturn V Workshop would be launched unmanned from Complex 39, KSC. About a day later, a three-man crew would be launched in an Apollo spacecraft atop the smaller Saturn IB vehicle from Complex 34. The spacecraft would rendezvous and dock with the workshop and occupy it for up to 28 days, during which time ATM experiments would be conducted. Later revisits of up to 56 days duration would be made, using the Saturn IB/Apollo combination.

The change in plans would simplify the previously announced 1971 mission; it would also augment the capability of that mission to perform space and earth-oriented research. Saturn V hardware from the Apollo program would be available to support the revised plan.

#### Hardware

Apollo Applications continued to develop and modify flight and test articles and their associated ground support hardware.

*Saturn I Workshop.*—The Workshop consists of three modules. The basic module for the Workshop is an S-IVB stage modified to provide living and working quarters for three men for up to two months. The Workshop includes an Airlock Module (AM) which will permit crew transfer from the CSM to the Workshop without extravehicular activity. The Workshop also includes a Multiple Docking Adapter (MDA) in which most of the AAP experiments are stored and to which the manned spacecraft and the LM/ATM are docked.

*Saturn IVB Workshop Module.*—Design and development of the Orbital Workshop (OWS) module is conducted at both the contractor's facility and in-house at the MSFC. The OWS module includes the crew quarters and habitability support equipment inside the converted S-IVB stage, passivation and meteoroid protection provisions, the external solar arrays, and Auxiliary Propulsion Systems of the Workshop Attitude Control System (WACS). The habitability support system includes water, food, and waste management systems. The OWS module has a thermal control and ventilation system and a caution and warning system which are inte-

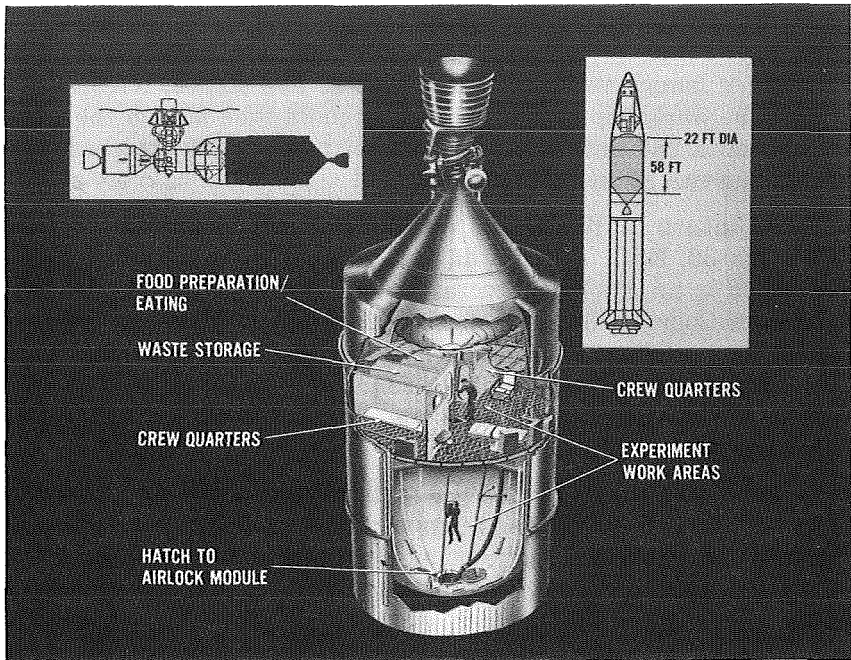


Fig. 1-13. Artist's concept of Workshop Module.

grated through the Airlock Module with corresponding overall cluster systems. (Fig. 1-13)

Significant design reviews completed included a preliminary requirements review at the MSFC for the solar arrays and the habitability support systems; preliminary design review for the WACS-APS; and a design review of the thermal control and ventilation system.

Development testing of mockups and Workshop systems continued in order to verify the design approaches. The OWS quick opening hatch mockup was tested successfully in a jet aircraft flying zero gravity patterns; ventilation system functions and noise characteristics were evaluated by tests in the engineering mockup at MSFC; and outgassing and humidity condensation and heat transfer characteristics of the OWS tank-wall insulation were determined during tests with an eight-foot diameter test tank in a thermal vacuum facility at MSFC. A rigging test of the meteoroid shield deployment system was conducted on the OWS development test fixture at the contractor's plant. All of these configuration-related tests essentially confirmed that the initial approach was satisfactory.

Production work on the S-IVB flight stage began. The engine, thrust structure, skirts, and accessory equipment were removed, and the structural assembly was installed in the insulation chambers at the contractor's facility. Mounting attachments to accept the modification kits are being provided on the structure/tank assembly. This work is to be completed by the time the flight modification kits are available for installation.

*Airlock Module.*—Major design phase of the Airlock Module was completed. The Module provides a pressurized connecting passage-way between the Multiple Docking Adapter at one end and the Workshop at the other. The Airlock Module is composed of a structural section and a tunnel consisting of a foreward compartment, an airlock, and an aft compartment. The module incorporates an electrical power system for the entire cluster, a central environmental control system, and the central control and display station for cluster operations. (Fig. 1-14)

The structural static test article was completed at the manufacturer's plant and successfully passed a pressurization integrity test before shipment to MSFC on May 1. At the MSFC test facility, the Airlock Test Article was mated with the Multiple Docking Adapter

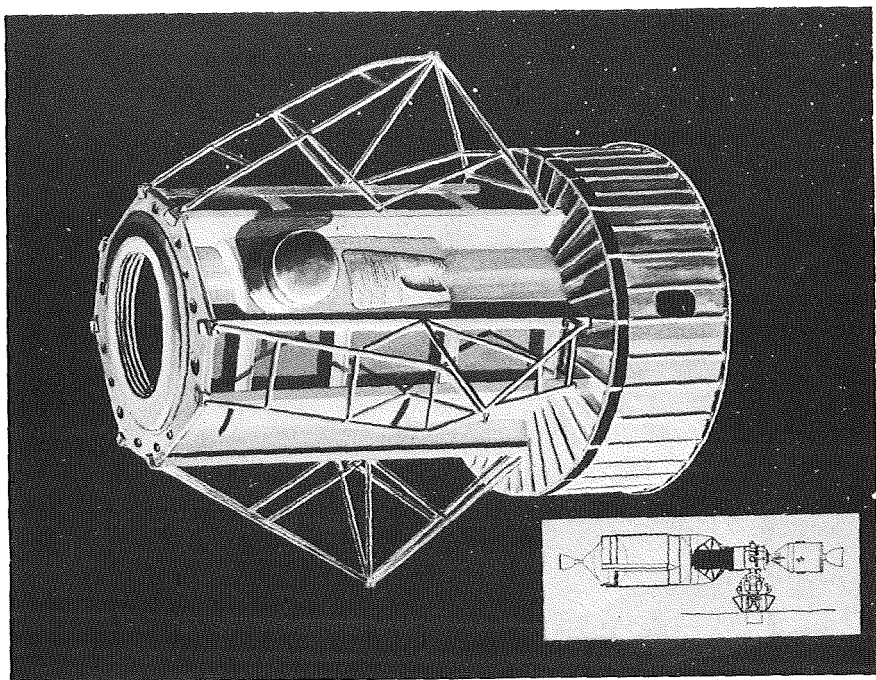


Fig. 1-14. Concept of Airlock Module.

static test article and the lower cylindrical payload shroud section. The combined test articles were being instrumented in preparation for static structural testing, scheduled to begin in the fourth quarter of 1969. The dynamic test at MSFC and the acoustic test at MSC are scheduled to be completed during 1970.

Airlock neutral buoyancy design evaluation and verification tests of the Airlock were nearing completion at MSFC.

*Multiple Docking Adapter.*—The Multiple Docking Adapter is being developed and fabricated in-house at MSFC. The module provides the ports for docking the CSM and the LM/ATM to the Workshop assembly. The MDA provides the interface connections necessary to allow these modules to function as an integral part of the orbiting cluster. It also provides a pressurized passage-way between the Airlock Module and the docked modules for astronaut and equipment transfer, and is used for storage of experiments and equipment during launch. (Fig. 1-15)

Activity was focused on the design, definition of test plans, and fabrication of the structural test article. The structural test article was pressure tested in March and delivered to the MSFC structural test facility for mating with the Airlock and Payload Shroud cylindrical section. Combined tests were being scheduled to commence in the fall of 1969.

A major portion of the Zero-G tests program was completed by

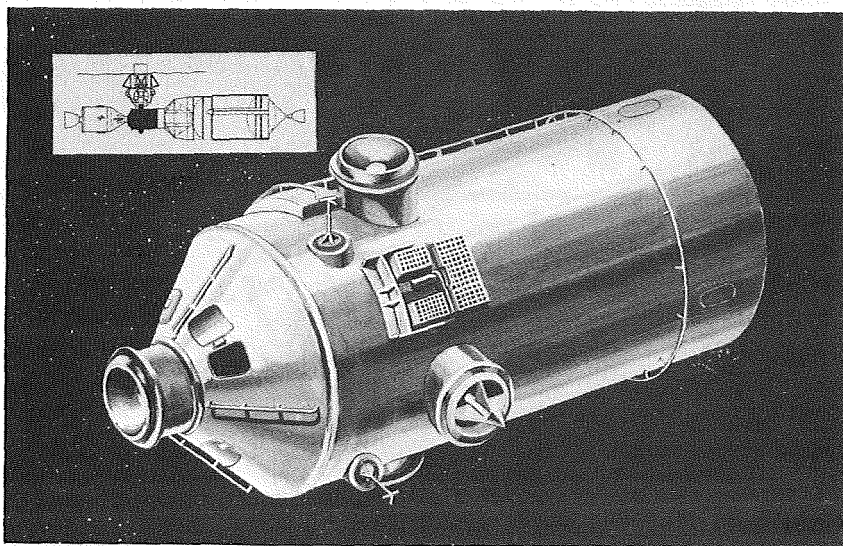


Fig. 1-15. Concept of Multiple Docking Adapter.

flying more than 140 parabolic flights of a jet aircraft at the Wright-Patterson AFB. Zero-G tests covered performance of mission tasks and use of mobility aid in MDA task simulators. MDA neutral buoyancy tests at the MSFC facility were continuing to verify design, installation, and mobility requirements for astronauts in moving experiments and equipment from the MDA to the Workshop.

*Apollo Telescope Mount.*—The ATM is a major module of the Apollo Applications Program, providing a sophisticated "optical bench" with supporting systems to study radiation from the sun. (Fig. 1-16) Critical design reviews evaluated the suitability of the design of components and subassemblies such as experiments, the rack structure, experiment package layout, and the control computer.

Development testing was either completed or continuing on experiments, a one-quarter section of the rack structure, control moment gyros, the control and display console, tape recorders, and the solar array development mechanism.

ATM zero gravity, neutral buoyancy, and one-gravity test articles underwent a series of design verification tests with astronaut participation. The tests were being performed to evaluate and finalize the EVA translation and work station concepts. The flight type structural test article was fabricated and was being instrumented to support the structural test program. Fabrication of the full scale thermal system and vibration test article was started, with completion scheduled for the last quarter of 1969.

*Lunar Module (LM-A).*—The ascent stage of an Apollo lunar module will be modified to contain the crew quarters and provide a pressurized compartment from which the crew can control the Apollo Telescope Mount and its various experiments. The descent stage will be replaced by the ATM structural rack with associated power, pointing equipment, and solar experiments. The LM-A contract negotiations were completed, and various documents were made part of the contract as a basis for continued design and development of the LM-A.

LM-A zero-gravity, one-gravity, and neutral buoyancy tests were continuing in conjunction with ATM testing. As part of these tests, the interior LM-A control and display layout was defined. Mockups were updated to latest configuration as the design became more definite.

The Apollo LM-2 flight article was transferred from MSC to the contractor's plant for use as the flight backup article. ATM subas-

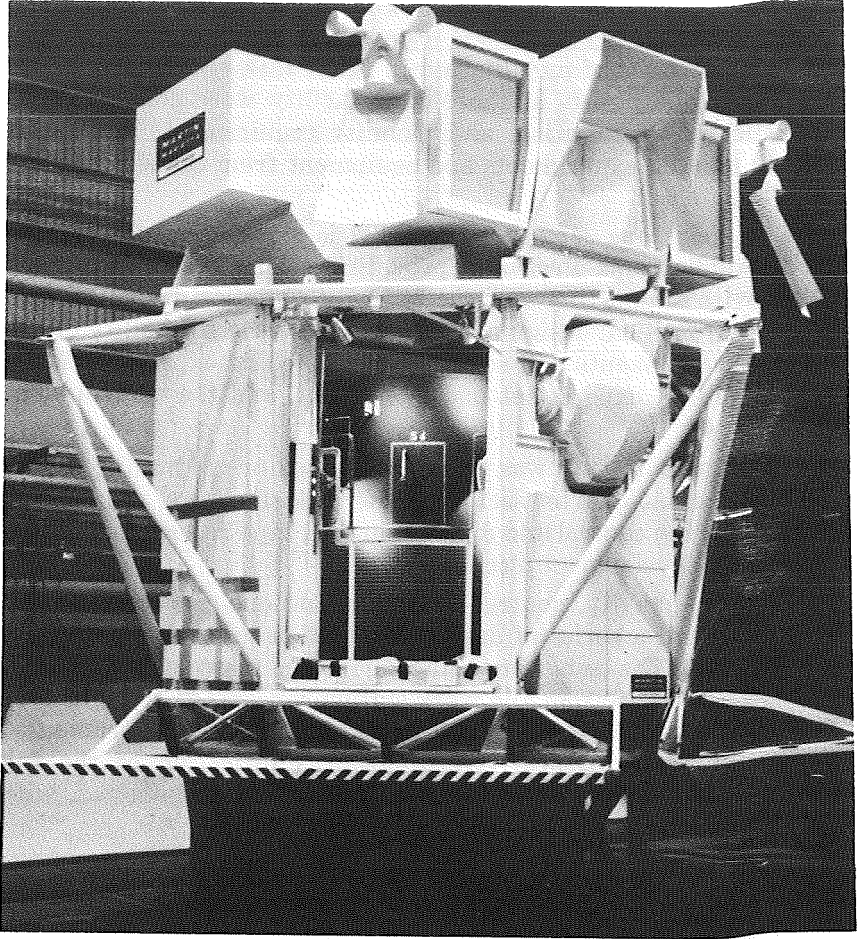


Fig. 1-16. Apollo Telescope Mount.

sembly testing, such as one-quarter scale plume deflector tests and radiator coating tests, was accomplished.

The LM-A guidance, navigation and control systems functions for AAP were defined. Toward the end of this reporting period various work items were deferred pending decision on a possible configuration change.

*Command and Service Module.*—The Apollo Applications CSM is derived from the Apollo Block II spacecraft with the basic objective of exploiting to the maximum the capabilities of Apollo hardware to accomplish the AAP missions. Unmodified systems sub-

jected to operational duty cycles in excess of Apollo performance requirements must be analytically or test verified for endurance under operating environments for 56-day missions. The Apollo Block II CSM must be modified to provide the 56-day mission greater maneuvering capability and adaptability to the AAP thermal and space environments.

The verification ground test program for CSM systems was reviewed in February. Approximately 500 subsystems and components were analyzed to determine the extent of additional testing required for AAP beyond that accomplished in the Apollo Program. Approximately 40% of the items analyzed were found to require some additional tests. In a series of meetings with the contractor, NASA finalized specific verification test plans for all CSM systems. The plans were published in mid-June.

Identification of major ground tests required for the AAP CSM consisted of service module (SM) static load, vibration, and acoustic tests, and a systems test for the modified SM reaction control system. The Apollo Program office transferred Block II test articles to AAP to accommodate these tests.

*Ground Support Equipment.*—The AAP makes maximum use of existing Apollo hardware, facilities, ground support equipment and logistic support. Launch complexes 34 and 37 at KSC have been deactivated and were being sand blasted and repainted to preserve their operational capability for AAP launches. Necessary maintenance is being performed during the standby storage period.

To make maximum use of present hardware, NASA decided to use an existing Apollo Acceptance Checkout Equipment (ACE) station from the Apollo program for the checkout of the ATM at MSFC. Additionally, a GSE Management Plan was being set up to assure identification, location, access, maintenance requirements, and availability of useable GSE in support of AAP flights.

### Experiments

The experiment payloads for the Apollo Applications missions were further refined. Forty-five experiments—grouped in the categories of medical and behavior, science, technology, engineering, and Department of Defense—were being assigned to specific missions.

*AAP-1/AAP-2 Workshop Mission.*—Emphasis on medical and behavior experiments; operation of science, technology, engineering, and Department of Defense (DOD) experiments.

*AAP-3A Revisit Mission.*—Repeat of medical and behavior and

other experiments launched on AAP-1/AAP-2; operation of additional experiments launched on AAP-3A.

*AAP-3/AAP-4 ATM Mission.*—Emphasis on operation of ATM solar astronomy experiments; repeat of medical and behavior and other experiments launched on previous flights.

Work on the medical and science experiments was proceeding. Integration and design requirements were being established, and certain contract work was initiated. Hardware development was started on most engineering and DOD experiments, and the hardware of all technology experiments was being fabricated.

The five ATM solar astronomy experiments being developed for the AAP workshop are the White Light Coronagraph, the X-Ray Spectrographic Telescope, the UV Scanning Polychrometer/Spectroheliometer, the Dual X-Ray Telescopes, and the UV Spectrograph/Heliograph. Two H-Alpha telescopes were also being developed as an aid to experiment pointing. Design was essentially completed or nearing completion on the experiments.

Thermal mechanical units (TMU's) have been manufactured, tested, and delivered for all the ATM experiments. The TMU's were tested in thermal vacuum chambers simulating space conditions. The thermal vacuum tests demonstrated the ability of the experiment thermal control systems to maintain the extremely high degree of thermal stability required for proper operation of the experiments. Several of the TMU's were also vibration tested, resulting in modifications in some cases to improve the vibration resistance of the experiments.

Manufacture of the prototype qualification units continued, with qualification scheduled to start for most of the experiments in late 1969. Qualification testing has already started for Dual X-Ray Telescopes.

### Operations

Operational mission planning activities continued in the several panels and planning groups. Alternate and backup mission plans were evaluated to ascertain the effects on system/hardware requirements. A baseline reference mission document was published to define to all operational elements the planned mission events and the associated minimum allowable systems performance and operational requirements.

A range safety study was made to assess the impact of using the spacecraft propulsion system insertion technique for orbital insertion of the CSM. The study results were to culminate in a range

safety "package" and briefing to the staff of Air Force Eastern Test Range for their evaluation and approval. Also, NASA initiated a study to investigate the possibility of establishing an automated flight activities scheduling system to be used by all operational organizations for both premission and real time analyses.

An EVA working group was formed to establish AAP EVA requirements, particularly for ATM film retrieval. EVA concepts were proposed and neutral buoyancy tests were made to validate the concepts and attendant astronaut procedures.

### ADVANCED MANNED MISSIONS

The Advanced Manned Missions office was primarily occupied with activities in support of the Space Station and Space Shuttle efforts. In both cases, part of the required technical and engineering staff was detailed from the Advanced Missions Program office to assist in getting these efforts underway.

Space station and transportation systems have been the subject of numerous studies over a period of years. Space station configurations considered in the studies have ranged from minimum-modification Apollo Applications workshops to very large earth orbiting stations. The results of these studies form the principal basis upon which the Agency based its decision to proceed into the Phase B, or program definition, of a Space Station Program.

Effort was continued to improve the capability to estimate the cost of future programs. All advanced study work statements, including those for the Space Station Phase B efforts, now have an added requirement that cost, schedule, and technical performance data generated in the course of the studies be reported consistently against a detailed format. Such reporting makes it easier to examine potential high cost areas. The data acquired in this manner will make a much improved costing baseline available for the analysis of future programs.

Experiment payload planning was directed mainly toward the experiment program to be conducted in the Space Station. This activity is both important and complex: important, because this is a major payoff area for the space station; complex, because of the large number of potential investigators, institutions, and agencies involved. In support of the Space Station Phase B effort, NASA's Integrated Payload Planning Activity has achieved a significant milestone by bringing together for the first time an Agency-wide program of experiments suitable for conduct during extended earth-orbiting missions. This sample experiments program represents a consensus among NASA's three major program offices:

Manned Space Flight, Space Science and Applications, and Advanced Research and Technology. Inputs to this effort were received from NASA's various planning and working groups, and panels. Scientific and technical expertise was furnished by the Manned Spacecraft Center, the Marshall Space Flight Center, and the Langley Research Center.

The Advanced Manned Missions Program office has been cooperating with other agencies and private enterprise in two manned undersea projects with a view toward gathering data and experience which will be useful in planning for long duration space missions. The two missions have in common the characteristics of long duration, stressful environment, significant degree of inherent hazard, isolation, and highly motivated crews.

In the TEKTITE project, four marine scientists lived and worked on the ocean floor for 60 days under saturated diving conditions. (p. 122) Marine science objectives provided the meaningful goal necessary to maintain a continuously high degree of motivation. NASA's interest was primarily biomedical and behavioral. Over 100,000 bits of behavioral data alone were gathered to be analyzed. Reactions to living, working, and recreation were assessed by systematic observation, by automatic event recording, and by subjective opinion. Measures were made of group cohesiveness and of the manner in which each crew member adjusted to other crew members, to the environment, and to assigned duties. Physiological measurements were made to evaluate the effects of various activities both inside and outside the habitat. As a result of the TEKTITE demonstration, which lasted much longer than any manned space mission to date, the interested agencies concluded that men can perform meaningful scientific work in a stressful environment for up to 60 days.

NASA was also preparing to participate in the Gulf Stream Drift Mission. The primary objectives of the mission are to observe and collect oceanographic, topographical, and geophysical data while drifting in the Gulf Stream for a period of thirty days. Nominal depth for the mission is 600 feet with excursions to 1,800 feet; distance to be traveled is approximately 1,500 miles. A heavily instrumented submersible, the "Ben Franklin," will be used. It carries a crew of six and maintains nearly sea level atmospheric composition and pressure. NASA is providing one crew member who will gather information for possible use in designing future spacecraft. His attention will be concentrated on mission and experiment operations, evaluation of habitability, and maintenance and repair.

One safety study was completed, two additional studies were underway, and safety guidelines and study requirements were integrated into the Space Station Phase B Definition study.

A contract study of an Emergency Earth Orbital Escape Device was carried out under direction of the Manned Spacecraft Center (MSC). The objective of the study was to analyze various emergency escape devices from a space station in earth orbit. The emphasis was on a three-man single purpose escape system for which a conceptual design and a preliminary program definition plan, including gross costs and schedules, were prepared.

The MSC also contracted for a Space Station Safety Study. Its objective is to develop a set of space station safety guidelines and criteria to support the Space Station Phase B Studies and subsequent efforts on the design of spacecraft.

A Lunar Emergency Escape to Orbit Vehicle study is expected to develop a conceptual design for a rudimentary vehicle capable of providing a means of emergency return to lunar orbit for two astronauts in the event of an emergency on the lunar surface. The study is being conducted by the Langley Research Center with contractual support.

A set of safety guidelines was prepared and furnished to the Space Station Program Definition study contractors as part of the work statement. In addition, the Phase B contractors were instructed to conduct a special emphasis task on "Systems Safety Analysis." Each contractor was required to establish an assistant program manager for safety and to issue a separate systems safety analysis report as a part of the documentation of the Phase B Definition study.

### SPACE STATION PROGRAM DEFINITION

Based on an Agency decision to proceed into a Phase B, or program definition, phase of a Space Station activity, the advanced manned missions program office prepared a statement of work and a request for proposals to conduct a contracted Phase B study effort utilizing FY 1969 study funds. After award of the 2 parallel study contracts, one study will be managed by Marshall Space Flight Center and one will be managed by the Manned Spacecraft Center. The study contracts will be for an 11-month period with completion expected by August 1970.

The Space Station concept selected for study is a 12-man station, operational in the mid-70's, capable of modular growth to accommodate approximately 50 men in later years. The Space Station is to be a centralized facility in space to conduct research and devel-

opment in many disciplines and to serve as an orbital operations and maintenance center for unmanned satellites. The station should have a useful life of at least 10 years with maintenance and resupply. A primary objective of the study and of the Space Station program itself is a major reduction in the cost of space operations. (Fig. 1-17)

The major purpose of the Definition studies is to define and

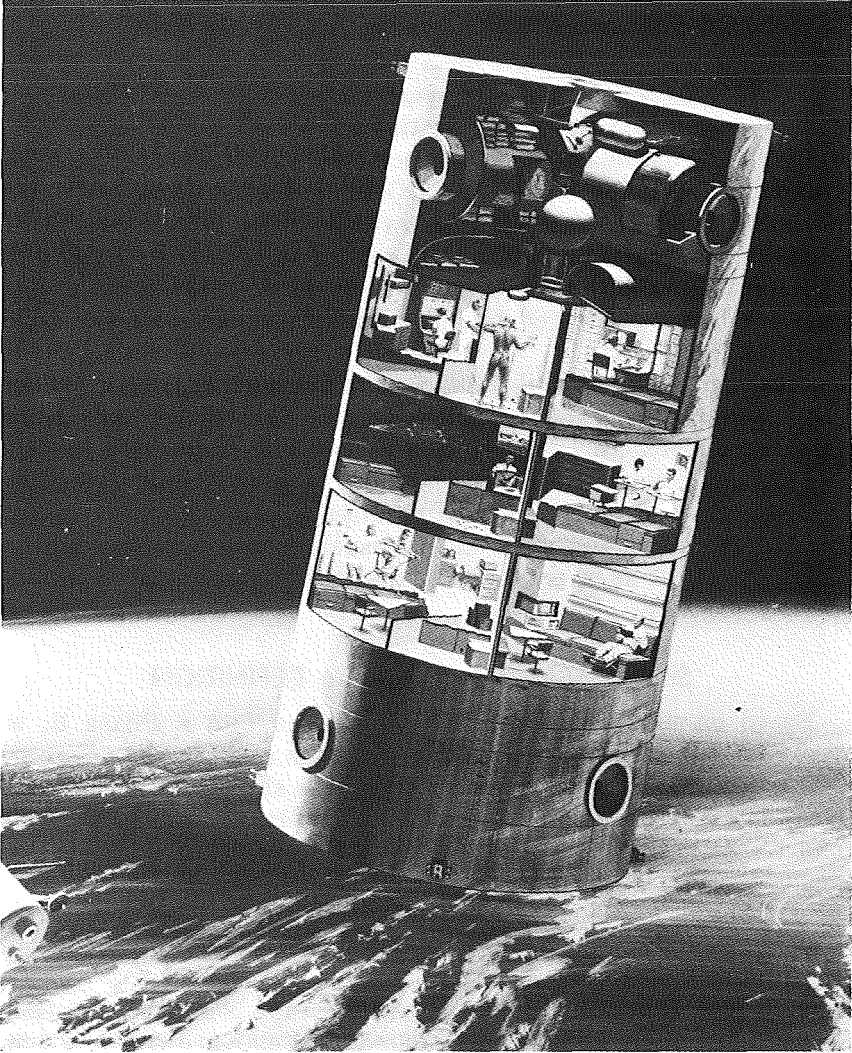


Fig. 1-17. Artist's concept of 3-deck, 12-man space station.

evaluate the preferred concepts for the Space Station Program. Such evaluation would include the core station modules, the payloads and payload modules, the logistics system, operations, and facilities. It would also include development of technical and management data from which NASA can make a selection of a recommended single program concept for possible Phase C Design effort. Other in-house and contracted activities in the area of experimental payload modules, logistics vehicle, and supporting systems are involved in the total program definition effort.

A Source Evaluation Board (SEB), with members representing all elements of NASA, was appointed to review and approve the Phase B work statement, to evaluate the proposals submitted, and to report to the Administrator (the Source Selection Official). The Request for Proposals was issued late in April, proposals were received on June 9, and the source evaluation took place during June. (The SEB findings were submitted to the Administrator during late July, when two contractors were selected to conduct the studies.)

To provide management to the Space Station Phase B effort, a task group was organized under the direction of the Deputy Associate Administrator for Manned Space Flight. This group will have the prime responsibility within NASA for management of the Space Station activities, for integrating and evaluating study results, for preparing overall program plans, and for providing the documentation necessary to obtain an agency decision relative to initiation of a Phase C effort. A field director for the Space Station will report to the task group director and will be responsible for integration of study efforts between centers and other elements of NASA. The field director's office will be at the Manned Spacecraft Center.

### SPACE SHUTTLE TASK GROUP

Four studies were initiated in February to determine the feasibility of a low cost transportation system and to propose conceptual design descriptions of three classes of vehicles. The three classes to be studied were the low cost expendable launch vehicle with an advanced reusable spacecraft, the one-and-a-half stage partially reusable vehicle with expendable tanks, and the fully reusable vehicle with recoverable booster. (Fig. 1-18)

These Integral Launch and Reentry Vehicle (ILRV) studies, initiated under the direction of the Advanced Manned Missions Office but now managed by the Space Shuttle Task Group, were for a spectrum of earth orbital round trip transportation systems. Such

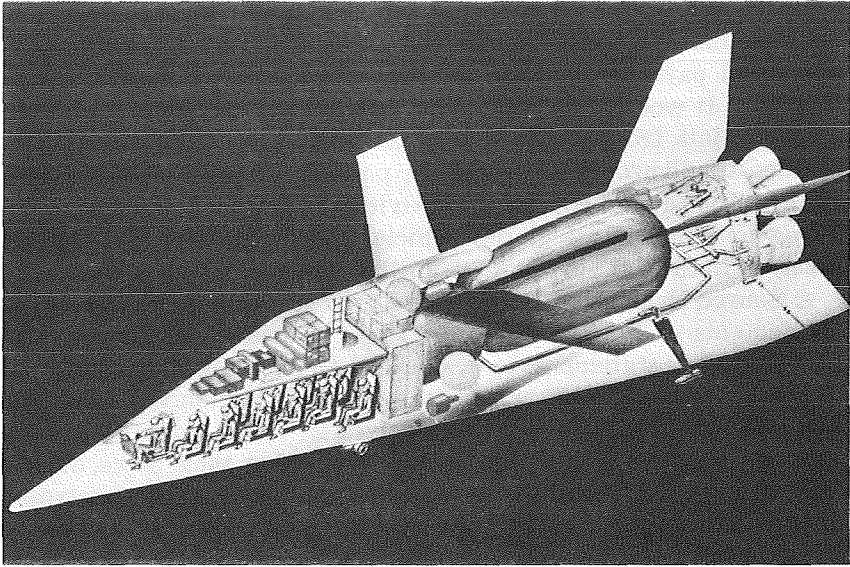


Fig. 1-18. Space shuttle reusable vehicle.

systems should meet the following conditions: Be (1) substantially less expensive than present systems in the recurring cost of operational missions; (2) significantly safer vehicle systems; and (3) versatile and flexible enough to permit the transportation system to be used for more than purely logistic missions.

A common set of mission characteristics and guidelines were established for all four studies:

- to seek major reductions in the cost of recurring operations by planning to reuse systems with a minimum of refurbishment;
- to use vertical launch systems with horizontal landings at fixed land sites;
- to design low cost expendable elements for simple, easy operational use;
- to keep ground support operations and equipment to a minimum for quick turnaround time;
- to provide a shirtsleeve environment with low "g" forces for passenger comfort;
- to allow for large integral cargo holds;
- to provide for passenger and cargo unloading through intra-vehicular transfer;
- and to design vehicles large enough to accommodate a two-man crew and ten passengers.

NASA held the first interim review of the ILRV studies during the last week of April at the respective Centers directing these efforts. A short briefing was presented to the Associate Administrator for Manned Space Flight the following week at Headquarters. Afterwards, the Agency asked the contractors to examine point designs and the sensitivity of these designs to payload diameter, weight, and volume. They were to report back to NASA on a spacecraft with a cargo capability of up to 50,000 lbs. and 10,000 cu. ft. which could be placed in a 270 nautical mile orbit at 55° inclination. Diameters of 15 feet and 22 feet were to be assessed against probable cargo requirements.

While the ILRV studies were in progress, NASA created the Space Shuttle Task Group for a joint DOD/NASA study of space transportation systems, and assigned the Director, Apollo Test, to head up the task group. This group was to accomplish the study in two parts—the first to be done separately by each agency, and the second to be done jointly. It was then to forward the results of the joint effort to the President's Space Task Group as a joint report.

The NASA Space Shuttle Task Group was staffed (from Headquarters and the Centers) to perform the agency study and to write a summary report. The Summary Report, published on May 19, covered efforts expended over the past few years to develop the Agency's needs for a future transportation system and present the programmatic requirements for obtaining a reusable shuttle spacecraft. Four appendix volumes, published on May 23, provided the detailed information and data to support the Summary Report: Vol. I, Missions; Vol. II, Desired Systems Characteristics; Vol. III, Vehicle Configurations; and Vol. IV, Program Plans.

In late May, NASA combined its task group with that of DOD for the joint study of the space shuttle system. This study resulted in the publication on June 16 of a classified joint summary report and a classified joint systems characteristics report. Both were forwarded to the President's Space Task Group. During this time, NASA also revised the four supporting volumes to the NASA Summary Report and published them on June 12.

As a result of this combined study and the publication of the joint NASA/DOD report, NASA decided to redirect the four study contractors, made additional study funds available to the contractors, and set a new completion date for mid-October, 1969. Contractors were to concentrate on the partially reusable and the fully reusable classes employing high performance LOX/LH<sub>2</sub> engines and a flyback air-breathing propulsion system for subsonic cruise and horizontal runway landing. Discretionary payloads were to be

investigated at 25,000 lbs. and 50,000 lbs., packaged for integral cargo holds of 15' diameter with 30' or 60' lengths and for a 22' diameter with a 60' length. Missions and systems characteristics as stated in Volumes I and II of the supporting appendixes were to apply.

Following publication of the NASA revised appendixes, the Space Shuttle Task Group began another study on June 16, which resulted in the publication of the Technology Program Plan on June 26. Five areas of technology development were identified as requiring intensive study. The technology aspects of the main engine propulsion system, having been under study and development for a number of years, were excluded from the plan. The five areas identified were Aerodynamics/Configuration Verification; Integrated Electronics System; Thermal Protection System; Attitude Control Propulsion; and Expendable Tank Construction. Each technology development program was defined to the point of task work descriptions, schedules, integration with other tasks, and recommended center assignments. The Technology Program Plan was sent to each participating Center on June 30, with a request for greater detailed breakouts of tasks they could undertake and what resources would be required.

## MISSION OPERATIONS

The mission operations activities of NASA's manned space flight program were concerned with flight crew training and support, operations support, mission control systems, launch information systems, and the Huntsville Operations Support Center.

### Flight Crew Operations

The successful completion of Apollo 9 and 10 provided the necessary final information for crew training on the lunar landing mission, Apollo 11. Key training devices—the LM mission simulator, the free-flight Lunar Landing Training Vehicle, and the cable-suspended Lunar Landing Research Facility—were brought into final operational configuration to support the first lunar landing training. All but the final two weeks of Apollo 11 training was accomplished. (Fig. 1-19)

The Apollo 12 crew was assigned and the members began their specific mission training.

Routine attrition factors reduced the active astronaut force to forty-seven. Pilot training for the scientist-astronauts selected in 1967 was essentially completed.

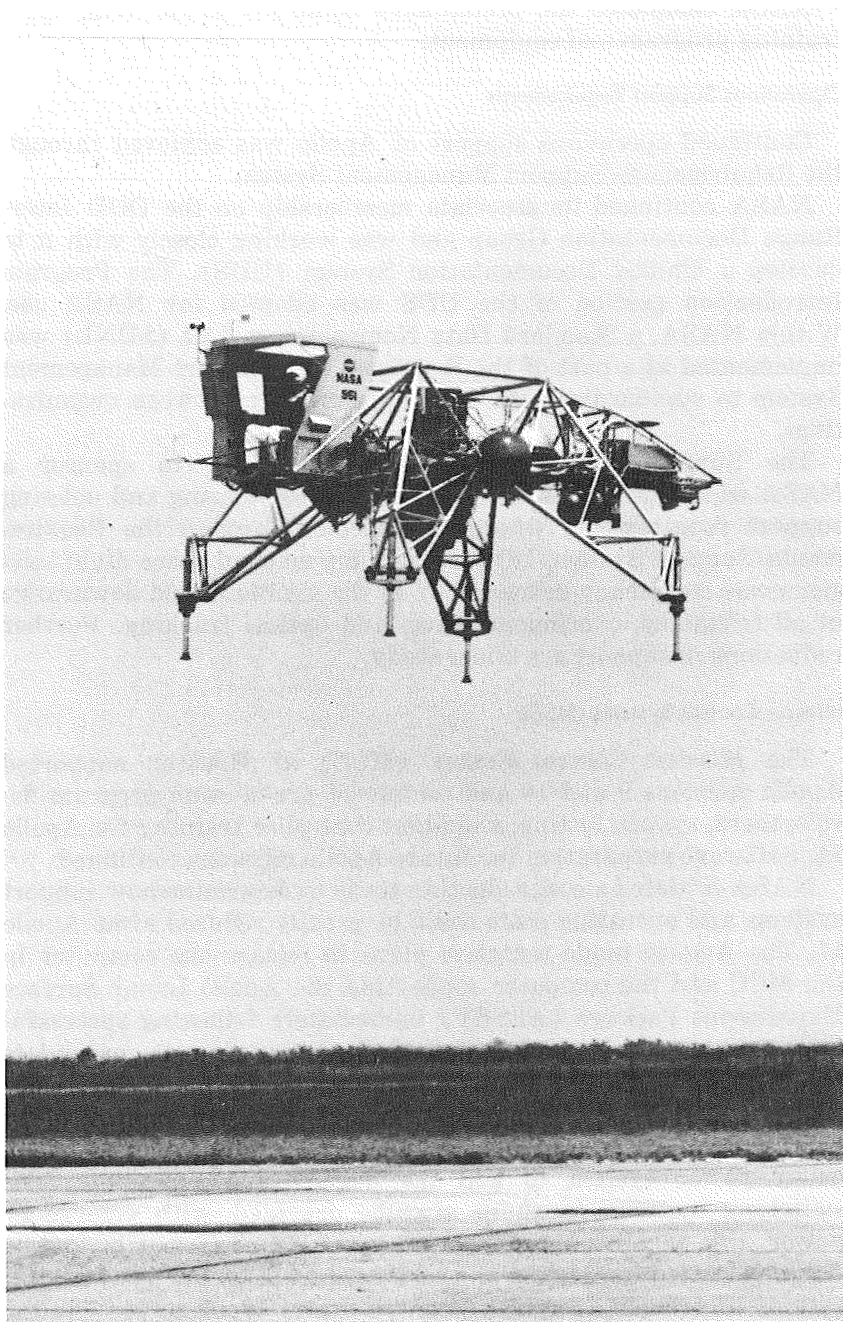


Fig. 1-19. Lunar Landing Training Vehicle piloted by Astronaut Armstrong.

NASA completed the preliminary definition of the AAP crew training program and equipment.

#### Operations Support Requirements

Continued operations support of Apollo was achieved through the Requirements/Support Management System.

NASA continued its associate membership on the DOD Inter-Range Documentation Group and was working closely with it to develop a Unified Documentation System (UDS). The Program Introduction portion of the UDS was adopted for NASA use. Within NASA, a Standard Data Nomenclature List (SDNL) was implemented as a part of the Requirements/Support Management System to standardize data ordering language between organizations.

The Support Requirements Office continued to sponsor a NASA-wide study, with a view toward consolidating and deleting support requirements wherever possible. Through the Requirements/Support System, DOD support for manned space flight missions was completely deleted both on the mainland and downrange in all telemetry, continuous wave, and optical tracking. Further reductions in support are under study.

#### Mission Control Systems (MSC)

The Mission Control Center (MCC) at Houston supported Apollo missions 9 and 10 and completed pre-mission program development, system testing, and flight controller training for Apollo 11. Software preparation for future Apollo missions continued.

NASA initiated a cost reduction study to determine how support systems and operating costs could be greatly reduced after Apollo 11. The Agency made tentative plans to release one computer in the MCC and the computer supporting the Apollo Lunar Surface Experiment Package (ALSEP) immediately following successful completion of Apollo 11. It also made tentative plans to consolidate the Simulation, Checkout, and Training System (SCATS) facility within the MCC and to provide SCATS computer support using MCC computers. In addition, NASA planned to expand the emergency power system to add the display and communications switching systems to those already provided with emergency power; this expansion was included in the FY 70 facility budget.

Work neared completion and testing started on the MCC modifications to provide an ALSEP control room. Work to provide the support capability required for the Early Apollo Scientific Experiment Package to be carried on Apollo 11 was completed. Work

continued on improved digital television display equipment as well as on a Communications, Command, and Telemetry System automatic computer restart system.

During this period, the spacecraft-TV scan converter project was completed as were the prototype Digital TV Display System improvements which provide for an efficient means to produce background and reference slides. Work continued on the computer aided communications analysis system which provides real-time predictions of spacecraft communications performance; only the final checkout and demonstration test of this system remained. A color projection TV system was procured, tested, and installed in the MCC.

In the Communications system testing, the Apollo Communications System command module and lunar module detailed tests were completed as were numerous individual component and special tests. Lunar landing communications simulation was started, and overall system performance evaluation tests, anomaly resolution, and problem investigation continued.

#### Launch Information Systems (KSC)

Launch Information Systems at KSC is composed of Launch Instrumentation Systems and Operational Communications. Launch Instrumentation Systems are the meteorological, acoustic, hazard monitoring, lightning warning, telemetry, display, data recording, and computing systems used during prelaunch tests, countdown, and launch of space vehicles at KSC.

The primary effort was supporting the checkout and launch of Apollo 9 and 10 and the prelaunch testing of Apollo 11. Several system improvements were completed. Special recertification equipment was installed to erase and test magnetic tape for reusability; digital tapes were being recertified at a rate of approximately 2,000 per month. NASA added mass storage equipment to certain computers to permit mass storage of telemetry measurements for recall and determination of test measurement trends. The Agency also procured data quality evaluation equipment to evaluate the telemetry ground station (date-core)-to-computer data interface. Such evaluation serves as an aid in software checkout and rapid troubleshooting if a failure occurs during operational periods.

The Operational Communications include voice, data, television, and timing systems used for prelaunch test and launch support. These systems successfully supported the Apollo 9 and 10 launches and prelaunch testing of Apollo 11. The only major communica-

tions equipment addition was a second (backup) operational television control console in the LC-39 Launch Control Center.

Because of the magnitude and complexity of the prelaunch voice communications system in the launch area, KSC was assigned an overall technical and management coordination role. Numerous interfaces between ground stations, consoles, and the spacecraft are involved in this highly critical system. The improved quality of voice communications in Apollo 9 and 10 demonstrated that this new approach was highly successful.

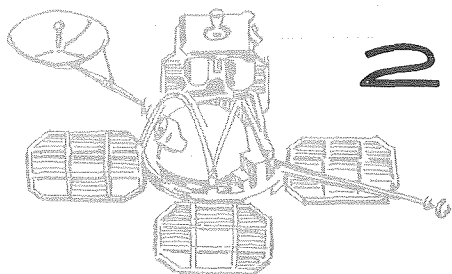
#### Huntsville Operations Support Center (MSFC)

The Huntsville Operations Support Center provided realtime consultative support to KSC during prelaunch and launch operations of Apollo 9 and 10. It also provided real-time support to the Houston Mission Control Center during the flight operations. The new 10-channel digital-to-TV display system which was installed late in 1968 became operational and supported both Apollo 9 and 10.

### SPACE MEDICINE

NASA was designated as the responsible agency within the Federal Government for protecting the earth against harmful contamination from personnel or equipment exposed to extraterrestrial environments. (*Federal Register*, Vol. 34: No. 1313, July 16, 1969.) Within NASA, that responsibility was redelegated to the Director of Space Medicine. As the responsible authority, and in cooperation with the Departments of Health, Education, and Welfare, Agriculture, and Interior, he would determine the beginning, duration, and termination of quarantine. He would also authorize the actual release of lunar-exposed persons, property, and geological samples.

The Lunar Receiving Laboratory (LRL), begun in 1966 at the Manned Spacecraft Center, was completed and certified. Focal point for the Lunar Sample Program, LRL provides quarantine, medical, and physical science facilities. The Interagency Committee on Back Contamination (ICBC) certified that the LRL was in operational readiness. The ICBC is composed of representatives of the Departments of Agriculture; Interior; Health, Education, and Welfare; the National Academy of Sciences; and NASA. As a basis for certification, biological procedures developed or approved by the ICBC both for quarantine and release of the astronauts were tested and validated prior to the Apollo 11 mission.



## SCIENTIFIC INVESTIGATIONS IN SPACE

The variety, number, and complexity of the unmanned spacecraft launched during the first six months of this year to carry out scientific experiments in space promised investigators an unprecedented return of data in the future. Some of the invaluable information already received by experimenters about the sun, the moon, the stars, the earth and its neighboring planets, and the regions surrounding them is outlined here.

### PHYSICS And ASTRONOMY PROGRAMS

Four spacecraft were orbited in the physics and astronomy programs: Orbiting Solar Observatory-V (OSO-V) on January 22; the cooperative Canadian-American ISIS-I January 30; Orbiting Geophysical Observatory-VI (OGO-VI) June 5; and an Interplanetary Monitoring Platform (IMP-G, Explorer XLI) June 21.

#### Orbiting Observatories

Similar in design and orbit to earlier spacecraft in the series, the 641-pound OSO-V satellite is made up of a rotating wheel to spin-stabilize the craft and a "sail" section that points at the sun. Its circular orbit—at an altitude of about 350 miles—places the instruments on board above the earth's atmosphere.

On the "sail" are a British X-ray spectroheliograph built by the University College in London and the University of Leicester; a Naval Research Laboratory spectroheliograph made to study the ultraviolet portion of the solar spectrum; and a spectrometer from the Goddard Space Flight Center to investigate the solar spectrum from 1 to 400 angstroms. The rotating wheel carries five experiments, including an experiment from the University of Paris to

monitor solar hydrogen and deuterium, and photometers from the Naval Research Laboratory to observe solar X-ray flux.

In other experiments Goddard Space Flight Center was monitoring solar and stellar gamma rays of low energies (5 to 150 Kev); the University of Minnesota measuring dim light coming from space at  $90^\circ$  to the earth-sun line; and the University of Colorado investigating solar radiation in far ultraviolet bands (280 to 370, 465 to 630, and 750 to 1,030 angstroms.)

OSO-V detected previously unobserved solar flare omissions which will help scientists understand disturbances in the ionosphere. It discovered that the red airglow of the earth (whose source is unknown) reaches an altitude of 300 miles and ends abruptly. Also, other data transmitted by the spacecraft indicated that earth's upper atmosphere may contain ten times as much deuterium as estimated.

OGO-VI, the last of the Orbiting Geophysical Observatories, like the others, carries many coordinated experiments. It resembles a six-foot box with appendages whose wings of solar cells give it the appearance of an insect. Stabilized in three dimensions, the 1,400 pound spacecraft keeps one of its faces in view of the surface of the earth. It is one of the POGOs—Orbiting Geophysical Observatories positioned in low polar orbits to study geophysical phenomena near the earth.

The 25 experiments of OGO-VI investigate latitude-dependent atmospheric phenomena during a period of maximum solar activity. They study atmospheric and neutron densities; electron density and temperature, and electrons trapped in the Van Allen belts; neutral atmospheric composition; ion concentration and mass; auroral particles and auroral and airglow emissions; magnetic and electric fields; VLF radio emissions; solar ultraviolet, solar cosmic, and solar X-rays; and galactic cosmic rays.

Seventy-nine of the 130 experiments aboard five operational OGOs in orbit (including OGO-I launched in 1964) continued to provide data. Analysis of a fraction of the data has supplied new information on the earth's magnetosphere and its shock fronts, on auroral phenomena, and on atmospheric chemistry on a global scale.

OAQ-II (launched December 7, 1968) demonstrated that astronomical observations must be extended from the visible region to the invisible ultraviolet region of the spectrum to understand stellar phenomena. For example, the satellite observed that some galaxies radiate more strongly (are "hotter") in the ultraviolet. Therefore, the basic relationships for estimating stellar distances may

have to be revised, since a crucial star's temperature would have to be revised.

OA0-II also disproved the theory that much of the mass of the Milky Way was composed of molecular hydrogen that radiated in the ultraviolet, and found that the night sky—outside of this galaxy—was not as bright as assumed, proving that there was much less luminous matter in the universe than scientists had believed.

#### Explorer XLI

Explorer XLI, IMP-G, is another of the Interplanetary Monitoring Platforms which investigate the earth's environment and monitor radiation in space (figs. 2-1 through 2-3). The 174-pound IMP-G is in a highly elliptical orbit reaching about halfway to the orbit of the moon. It carries 12 experiments from universities and industry, and one from Goddard Space Flight Center, which study cosmic rays, solar wind, and the interplanetary magnetic field. The studies provide data vital for spacecraft design and essential in planning future space missions.

#### ISIS-I

ISIS-I is the first of the Canadian-American satellites to follow

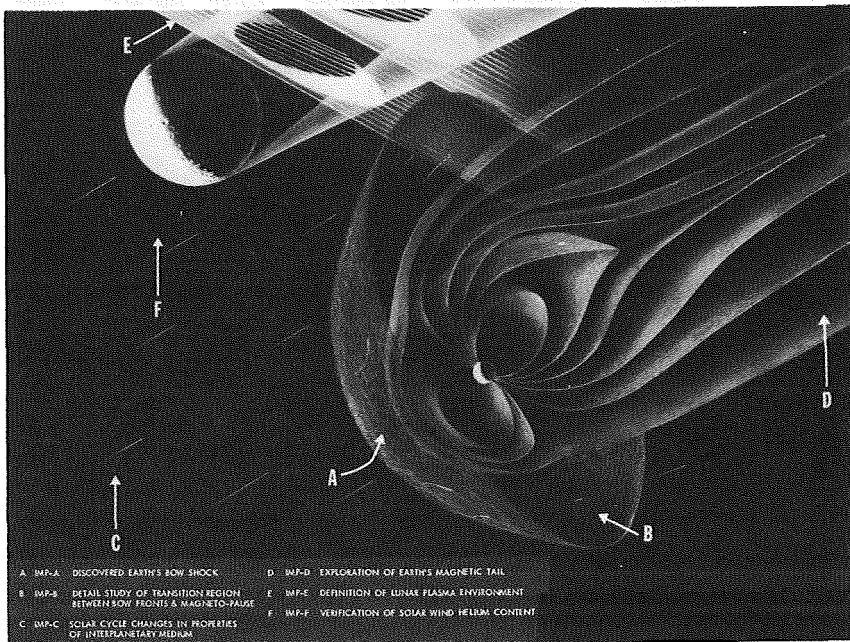


Fig. 2-1. Major scientific achievements of the IMP series.

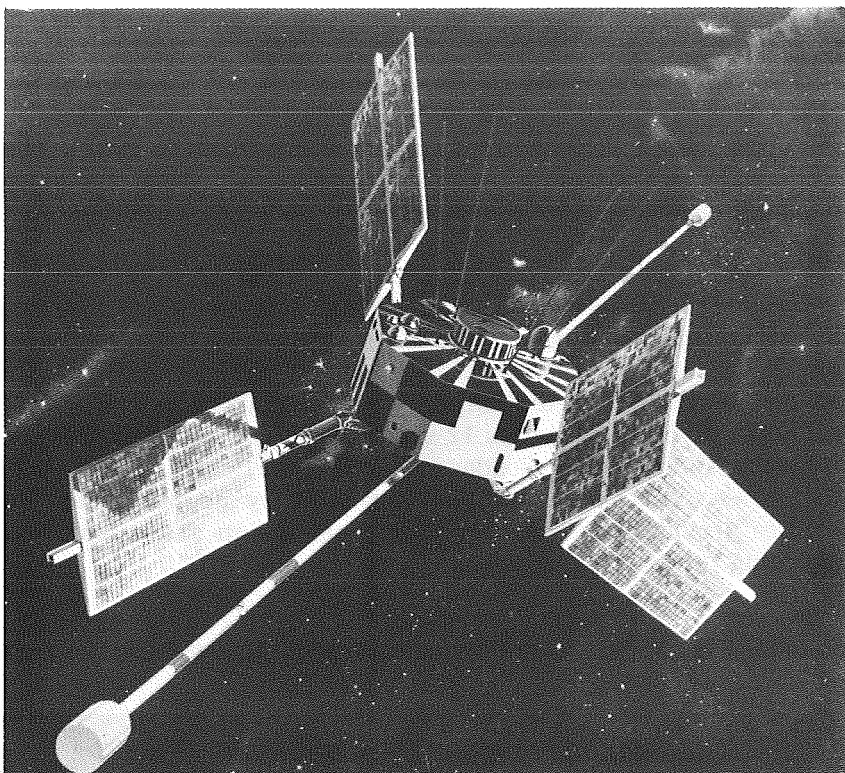


Fig. 2-2 Sketch of IMP.

the earlier Alouette series (Alouette I was orbited in September 1962; II in November 1965.) Like the Alouette spacecraft, this 523-pound spheroidal satellite was built in Canada and launched by NASA to help scientists understand the upper ionosphere. It does this by making radio soundings and direct measurements of the surrounding medium. (Fig. 2-4.) The radio soundings provide ionospheric data by remote sensing for altitudes from 200 to over 2,100 miles. ISIS-I carries ten experiments—fixed and swept frequency radio sounders; energetic particle detectors; electrostatic probes; an ion mass spectrometer; and a radio beacon. Data from the spacecraft were available to the U.S. and Canada, but other countries help acquire and analyze this information.

#### Sounding Rockets

Fifty-eight sounding rockets were launched into the earth's upper atmosphere for observations, including some in solar and

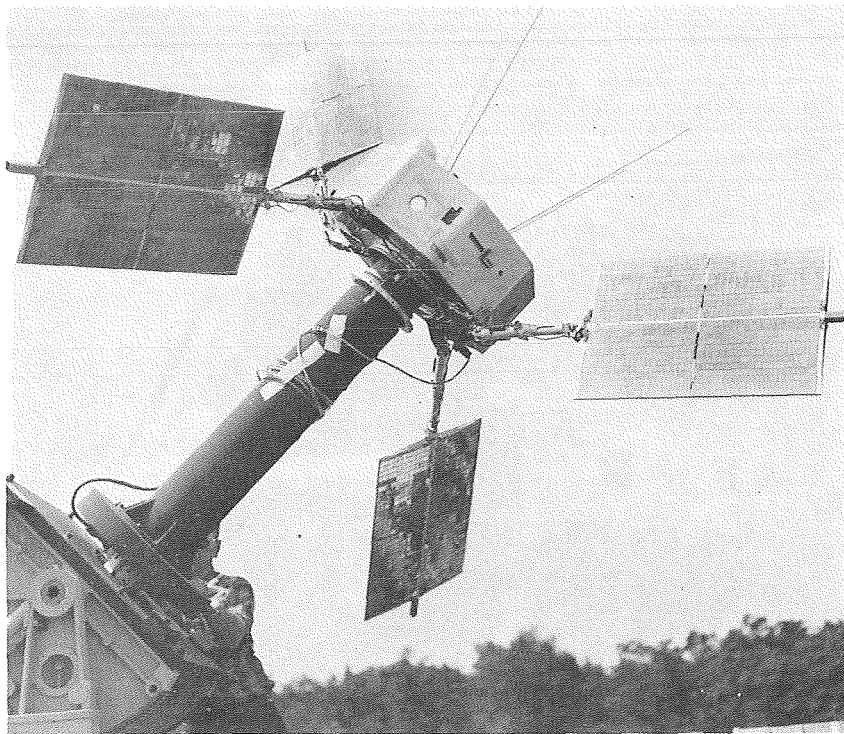


Fig. 2-3. IMP G.

stellar astronomy. They investigated ultraviolet radiation, stars in the X-ray spectral region, the ionosphere, the aurorae, electric fields, and energetic particles.

## LUNAR SCIENCE PROGRAM

### Apollo Lunar Surface Science Program

During the Apollo 8 mission—the first manned lunar orbital flight, December 21–27, 1968—the astronauts photographed major surface areas on the far side of the moon of interest to scientists and took some pictures of landing site 1 on its near side. These pictures (fig. 2-5) complemented the extensive coverage of the Lunar Orbiters. Orbiter's prime objective was to certify Apollo landing sites; consequently most of its photographs were taken at low sun angle to emphasize relief. The Apollo 8 pictures were taken through the entire range of sun angles, and are free from the mosaic effect and local rectification errors of the Lunar Orbiter pictures (18th Semiannual Report, p. 50.)

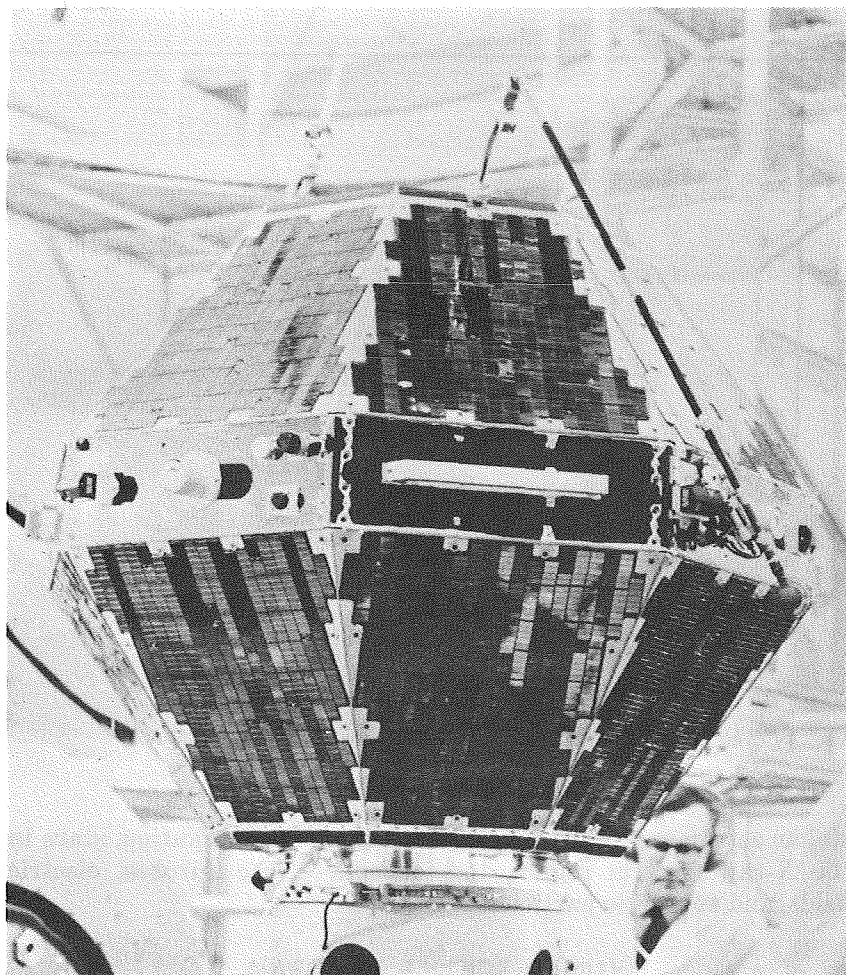


Fig. 2-4. ISIS-1.

The high sun angle pictures, emphasizing differences in surface reflectivity, provided more information on the lunar surface. Many bright new craters were observed, surrounded by bright ejecta blankets, making them appear star-like. Also, three relatively small craters (from 16 to 60 miles across) with extensive bright ray systems were found on the moon's far side. The photographs showed layering in the crater walls and slumping of parts of these walls. The low domes of the craters and flow line scarps are interpreted as evidence of volcanic action.



Fig. 2-5. Apollo 8 view of crater Goclenius.

The Apollo 10 pictures (fig. 2-6 and 2-7), which followed the same photographic plan as the Apollo 8 photographs, supplied clear views of landing sites 1, 2, and 3 (fig. 2-8). They are still being analyzed.

The observations of the astronauts during the Apollo 8 and 10 missions were important to the lunar surface science program. For example—

- The Apollo 8 crew felt that the moon was dark grey with a touch of brown; the Apollo 10 crew that it was brighter overall and more brownish. (No other colors were observed on the surface.)
- The astronauts could observe detail in lunar shadows, and great detail in “earthshine”.
- They were unable to detect transitory phenomena on the lunar surface, such as light flashes, eruptions, or meteor impact flashes.

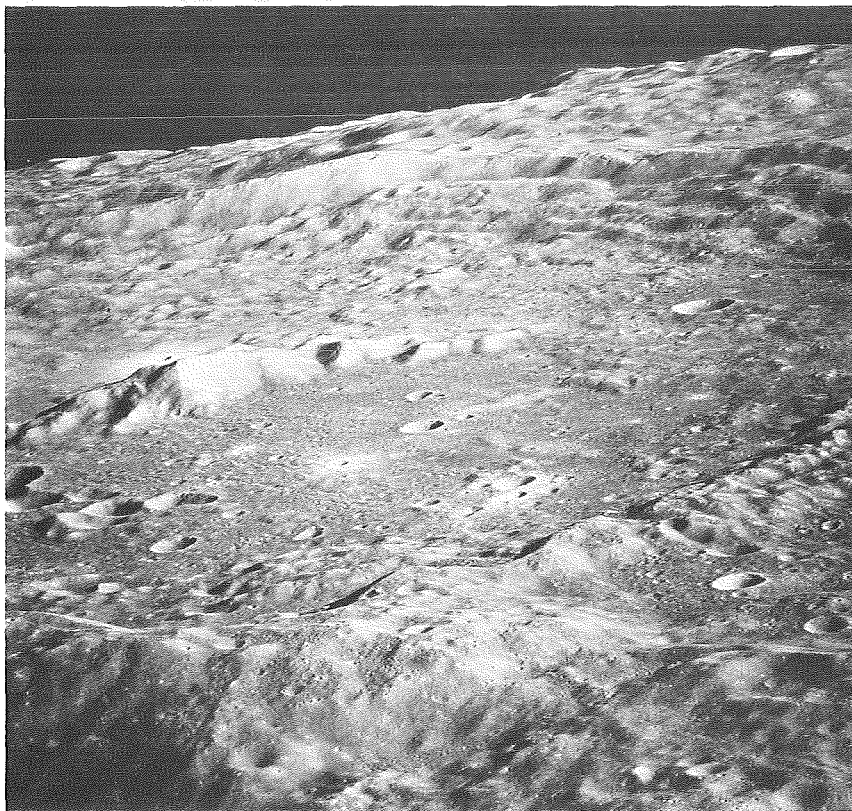


Fig. 2-6. Apollo 10 photograph of International Astronomical Union Crater No. 302 on moon's far side.

- To the astronauts, the appearance of the lunar surface changed considerably with the sun angle.

Also, of direct value to Apollo 11, was an increased understanding of the moon's gravity field resulting from the careful tracking of Apollo 8 and 10. This information complements the data supplied by the Lunar Orbiter flights that enabled the Jet Propulsion Laboratory to identify five mass concentrations (mascons) underlying the five ringed maria of the lunar near side. The nature and cause of these gravity-high mascons are unknown. Besides, the positions of various features of the moon's far side, which can not be mapped by earth based telescopes, were determined with greater accuracy on maps of Apollo 10 than they were on those of Apollo 8.

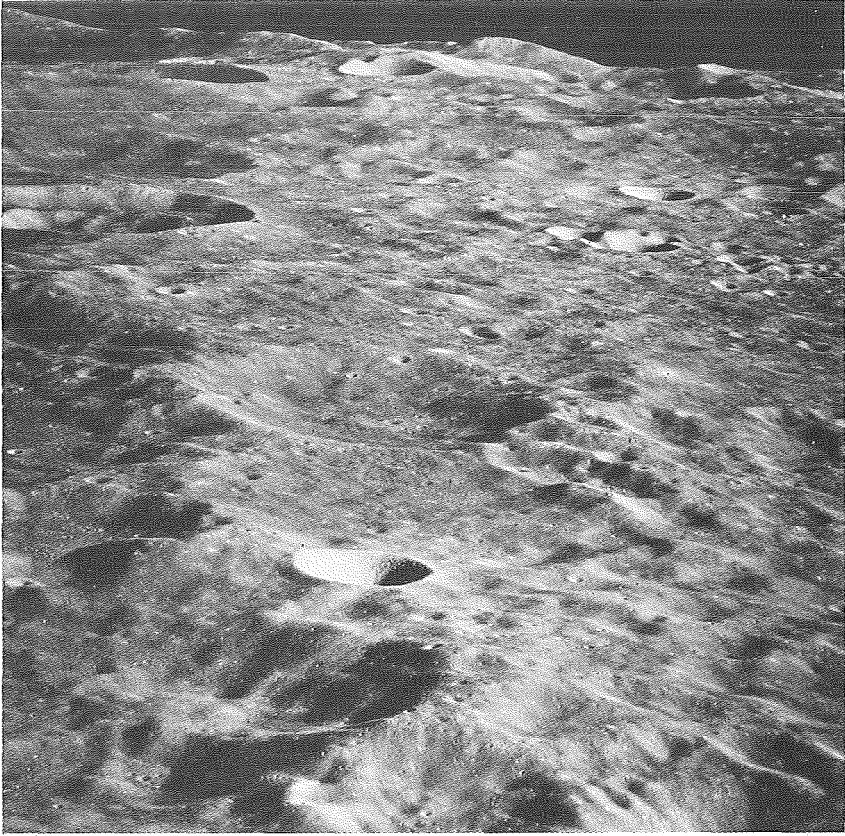


Fig. 2-7. Far side of the moon from Apollo 10 LM.

## PLANETARY PROGRAMS

### Mariner Mars '69

On February 24 and March 27, Mariners VI and VII were launched on flights which will carry them within about 2,000 miles of the surface of Mars to investigate the planet in late July and early August. These launchings marked the beginning of the final phase of the Mariner Mars '69 Program.

The spacecraft (figs. 2-9 and 2-10) are identically equipped, although they will carry out different missions at the time of the Mars encounters. Mounted on movable platforms are two television cameras, an infrared spectrometer, an infrared radiometer, and an ultraviolet spectrometer. Rotating and repositioning the platform

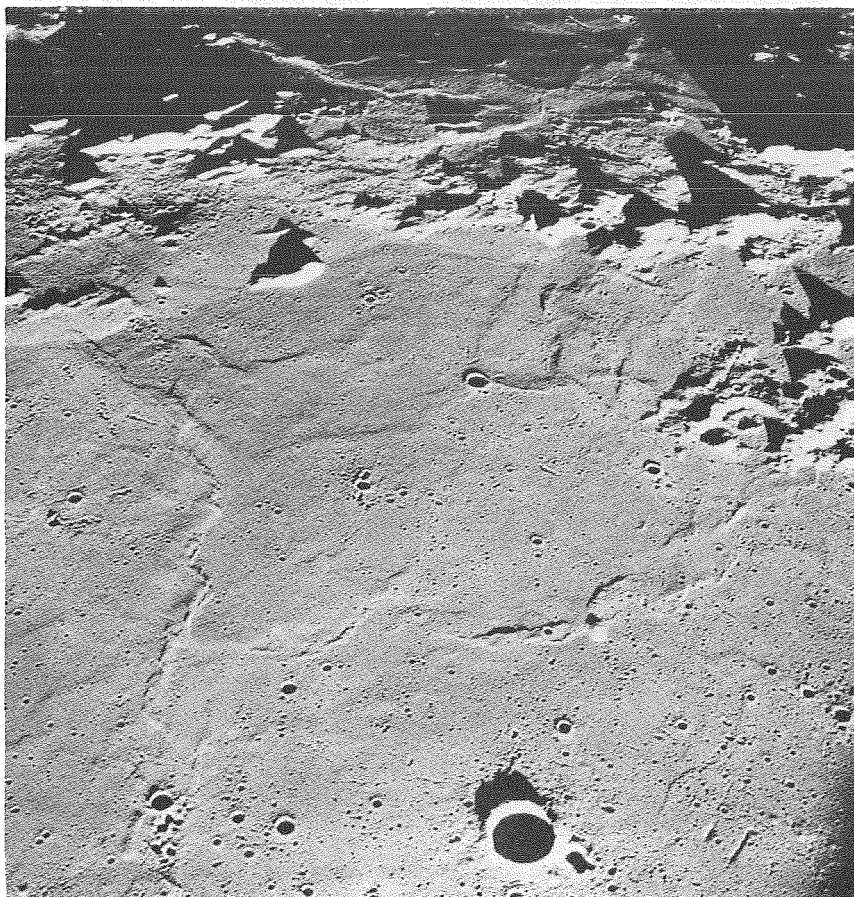


Fig. 2-8. Landing site 3 in the Central Bay seen from Apollo 10.

enables the instruments to view much more of the Martian atmosphere and surface than would be possible from a stationary position.

An equatorial pass of the planet is planned for Mariner VI, which, since its February launch, has operated as designed. It should commence encounter operations on July 28, when its long focal length TV camera will be aimed at Mars to take far-encounter or approach photographs. The pictures will be transmitted to earth over the spacecraft's radio high data rate system the next day, when the spacecraft is above the Goldstone, Calif. 210-foot tracking antenna; the transmission will be available for real-time viewing over commercial TV.

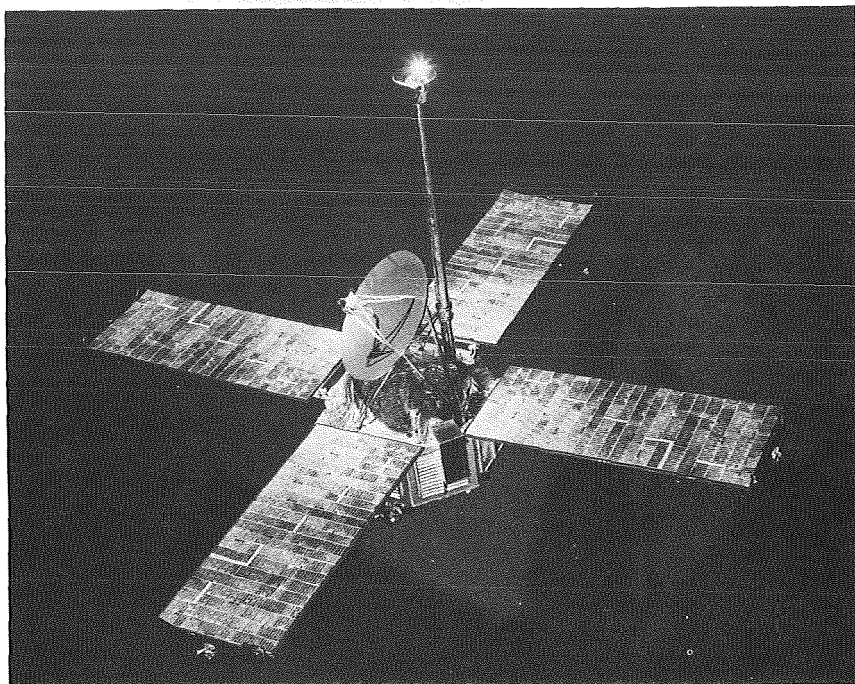


Fig. 2-9. Mariner Mars '69 spacecraft.

As Mariner VI nears the planet, the scan platform will again be repositioned, so that its remaining science instruments can view features of the Martian atmosphere and surface of interest to scientists. On July 31 (1:18 a.m., EDT) the spacecraft will be closest to the planet's surface—an estimated 2,165 miles away.

Mariner VII will approach the southern polar region of Mars. After transmitting far-encounter pictures, the spacecraft's scan platform will move into a position to obtain photographs and spectra of the Martian polar cap and regions surrounding it. Mariner VII will come within about 2,071 miles of the Red Planet at 1:00 a.m., EDT on August 5.

#### *Mariner Mars '71*

Major progress was made in the Mariner Mars '71 Program during the first six months of 1969. In February, the functional design for the spacecraft system was completed, and contractual arrangements for the Atlas-Centaur launch vehicle were begun. The mission's overall design was finished in April, and the detailed design of the spacecraft was completed in September. In addition,

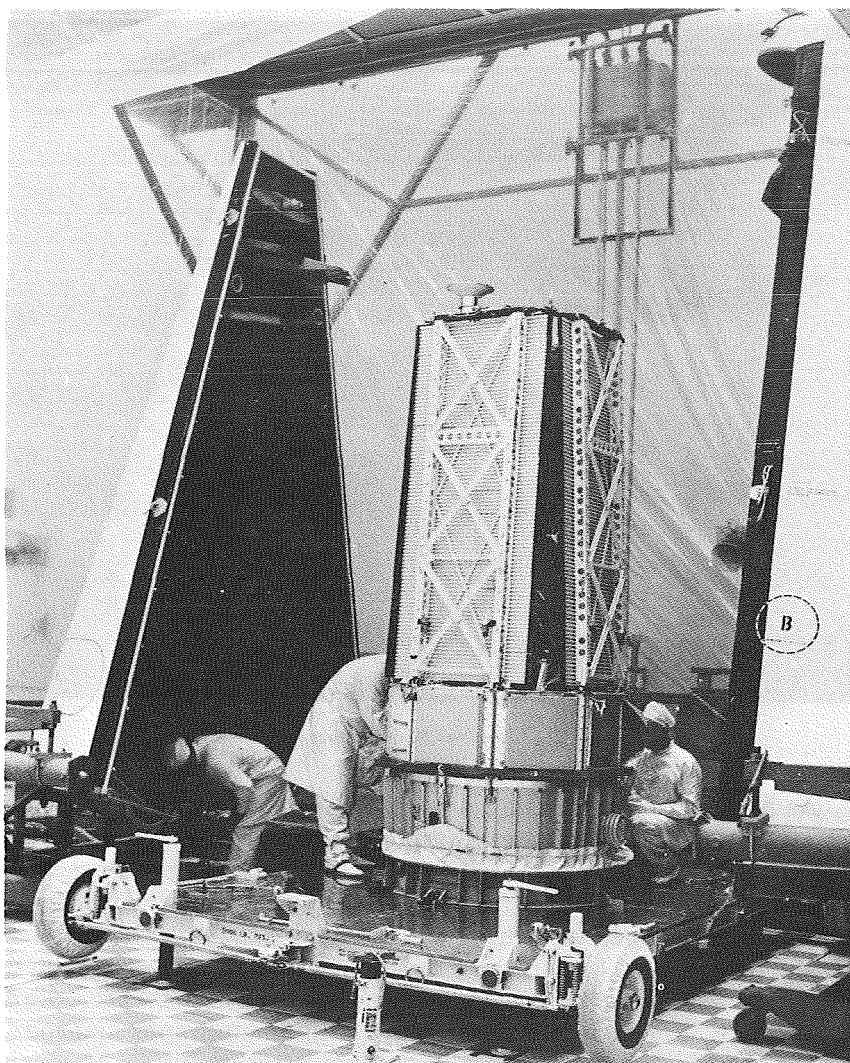


Fig. 2-10. Mariner VII being mated with its protective launch shroud.

22 major subcontractors were selected for the scientific instruments and spacecraft subsystems.

The Martian-orbiting spacecraft of Mariner Mars '71 will make maximum use of Mariner Mars '69 hardware (*20th Semiannual Report*, p. 64.) For example, the proof test model of the spacecraft for the 1969 flybys was being disassembled, inspected, and modified to become the proof test model for the 1971 mission.

## Viking

In addition to the Mariner flybys of Mars in 1971, NASA plans to send two instrumented spacecraft to the planet in 1973\* to collect additional scientific data, particularly emphasizing extraterrestrial life-related experiments. Each of the Viking program spacecraft will be made up of a soft lander of the Surveyor class and an orbiter of the Mariner type. The lander will photograph its landing site, search for organic compounds and living organisms, investigate the environment's capacity to support life, and make measurements to determine the composition and structure of the Martian atmosphere. The orbiter will carry out comprehensive surveys of the landing sites and study the planet's dynamic characteristics and atmosphere.

A contract was negotiated for building the lander, and scientists were asked to help plan the Viking project and develop instruments for it. Over 150 proposals were submitted, and 38 scientists were selected and organized into eight teams, to assure the maximum return of scientific data from the mission.

Langley Research Center was assigned overall Viking project management and responsibility for the lander. The Jet Propulsion Laboratory will manage the orbiter portion of the program and be responsible for tracking and data acquisition. Lewis Research Center will manage the Titan III-Centaur launch vehicle.

## Pioneer Spacecraft

Pioneers VI through IX, from widely separated orbits about the sun, continued transmitting data on solar activity and related interplanetary phenomena. Launched in 1965, 1966, 1967, and 1968, they detected significant solar activity in March and April of this year and made it possible to forecast disruptions of communications on earth, such as occurred in the arctic where radio communications were almost impossible for about a week due to the solar storm.

Pioneer E (or X), the last of this series, was being prepared for launching in August. Also, procurement contracts were under negotiation for Pioneers F and G—to be orbited in 1972 and 1973. These will pass through the asteroid belt and fly close to Jupiter. Their experiments (whose selection was completed in June) will measure the properties of energetic particles, magnetic fields, and cosmic dust throughout the mission. In addition, instruments on board will be able to make direct measurements in the infrared, visual, and ultraviolet wavelengths of the electromagnetic spectrum in the immediate vicinity of the planet and its atmosphere.

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\* The Viking missions were rescheduled to 1975, after this report was completed.

## Helios

In the Helios program—sponsored by NASA and the Federal Minister for Scientific Research, Federal Republic of Germany—two instrumented probes will be sent to about within 0.3 of an astronomical unit of the sun to collect more data on fundamental solar processes and solar-terrestrial relationships (p. 154). Launch of the first Helios probe was planned for 1974, with a second launch the following year.

## ADVANCED TECHNICAL DEVELOPMENT PROGRAM

Outer planet missions demand major technological innovations in telecommunications, data handling and storage, guidance, attitude control, on-board computing, and propulsion. Advanced development in these and related areas—guided and coordinated by system and subsystem studies—was proceeding.

For example, signal processing studies of high reliability star trackers resulted in the design of a preamplifier much less susceptible to noise saturation effects. Also developed was an improved electrostatically-focussed amplifier with a power output of 20–100 watts, which operated at efficiencies of 42 percent at 100 watts and 33 percent at 20 watts.

Another improvement was a cold electrode welding head for microelectronic packaging able to produce welds of wire with 10-mil insulation thickness, and, for the first time, to weld insulated wires without damage to the insulation of closely spaced adjacent wires.

## ADVANCED STUDIES

Further study of a “Grand Tour”—successive swingbys of Jupiter, Saturn, Uranus, and Neptune in the late 1970s—pointed up the advantages of two three-planet tours. These would be a three-planet mission to Jupiter, Saturn, and Pluto in 1977, followed by one to Jupiter, Uranus, and Neptune in 1979. Among the advantages of these three-planet missions are flybys of all five of the outer planets, shorter trip times, and avoidance of the potentially hazardous rings of Saturn.

The spacecraft for the missions would weigh about 1,500 pounds, carry 120 to 150 pounds of scientific instruments, and be launched by the Titan/Centaur/Burner II vehicle.

Initial studies have indicated the feasibility and desirability of a multiple-probe approach to explore the atmosphere of Venus. In this method, several probes would be carried aboard a parent

spacecraft and detached to penetrate the planet's atmosphere, providing almost simultaneous readings at widely separated points to better define the major dynamic processes which govern the Venusian atmosphere and its weather.

### BIOSCIENCE PROGRAMS

#### Biosatellites

Biosatellite D (Biosatellite III) carrying a primate was

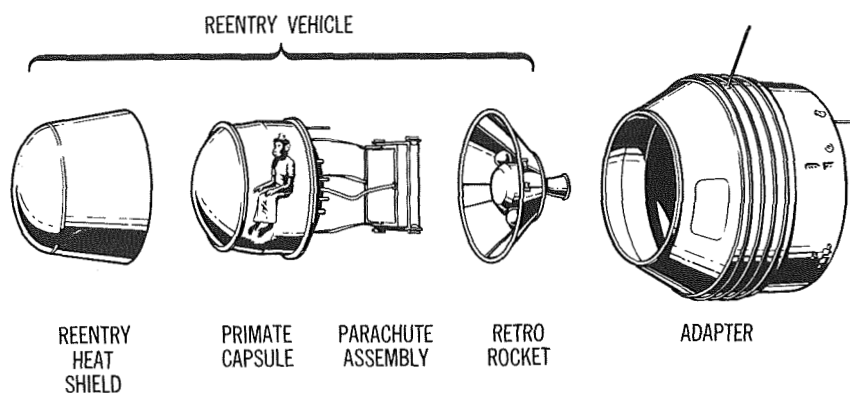


Fig. 2-11. Biosatellite III spacecraft.

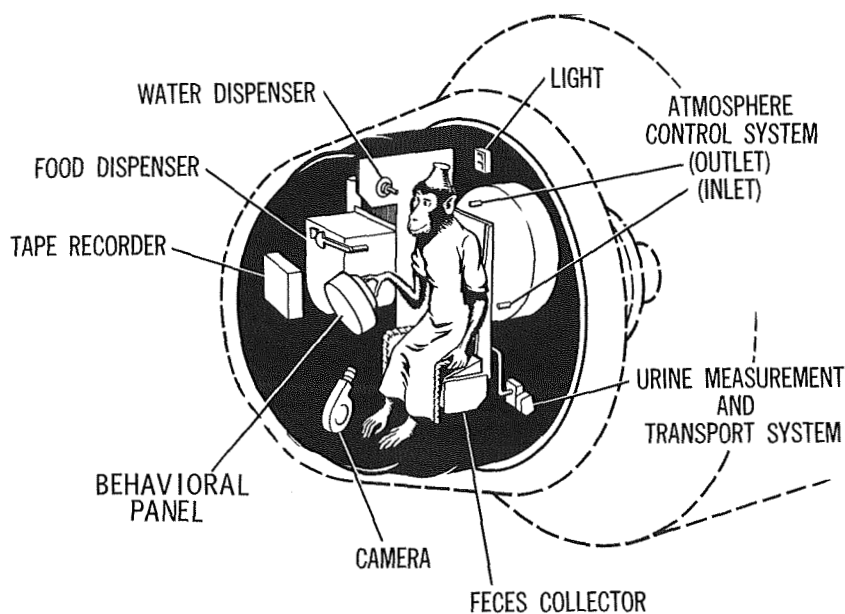


Fig. 2-12. Biosatellite III primate support systems.

launched on June 28 to orbit the earth at an altitude of about 200 miles. (Figs. 2-11 through 2-14.) The spacecraft systems performed as expected, and excellent physiological data on the condition of the monkey were recorded at all stations.

When the monkey's condition declined about 81½ days after launch, the satellite was returned to earth. The animal was recovered alive but died during the post-flight examination. Physio-

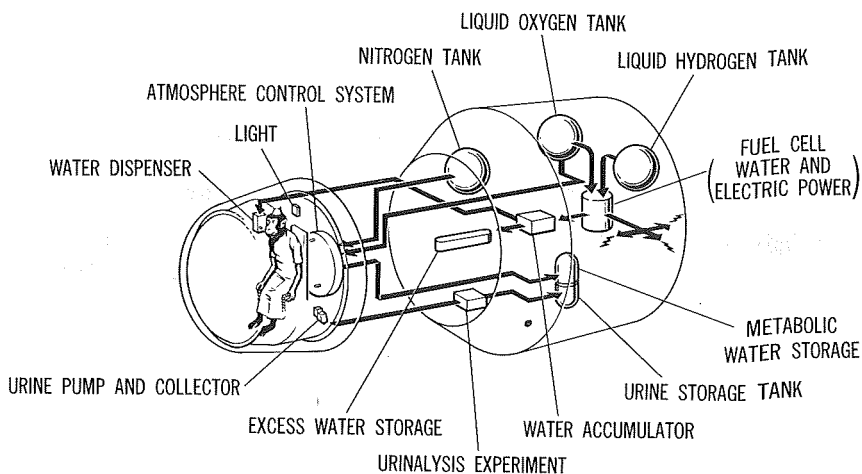


Fig. 2-13. Biosatellite III systems.

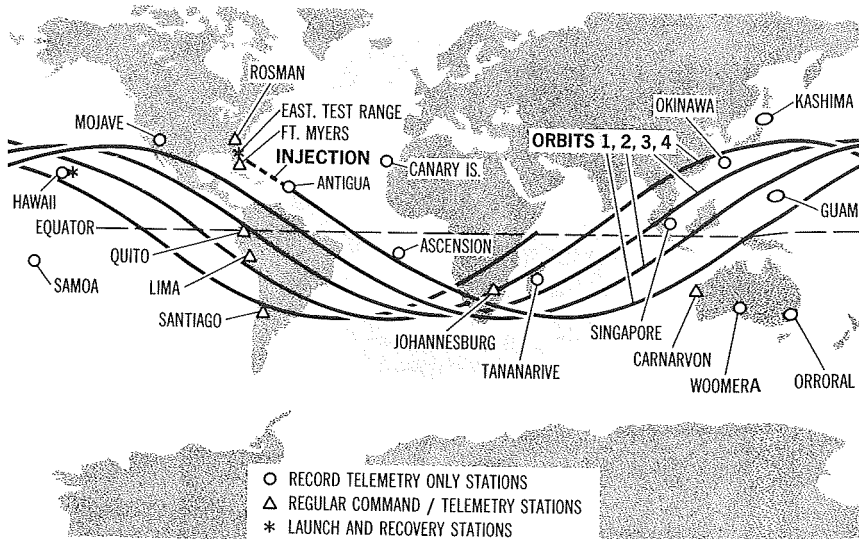


Fig. 2-14. Command, telemetry, launch, and recovery stations for Biosatellite III.

logical data were being analyzed. (The Biosatellite mission will be described in greater detail in the *22nd Semiannual Report*).

### Exobiology

Two of the science advisory groups organized to support the Viking 1973 Mars lander mission (*20th Semiannual Report*, p. 68) are the Active Biology and Molecular Analysis Teams. The five exobiologists making up the Active Biology Team will develop an integrated instrument for possible flight on this mission. It will use many of the techniques developed in NASA's exobiology program, and should be able to detect photosynthetic and metabolic activity, as well as any growth of living organisms found on the Martian surface.

The Molecular Analysis Team is composed primarily of organic chemists. They will use the gas chromatograph-mass spectrometer, being developed under their direction at the Jet Propulsion Laboratory, to analyze a sample of the Martian surface to see if organic matter is present—particularly organic matter of biological significance. Besides looking for organic matter in the surface sample, they will look for organic molecules in the planet's atmosphere, and determine the amount and condition of surface water. These preliminary experiments will not answer all of the questions about life on Mars, but should be able to indicate the presence or absence of life and organic molecules so that detailed analyses may be planned for future missions.

In addition, exobiologists were helping to develop an imaging experiment for the 1973 lander, and collaborating in the design of experiments for the photo interpretation teams on the 1973 orbiter.

### Planetary Quarantine

NASA continued developing techniques to control biological contamination and sterilize spacecraft intended to land on the planets, such as the Viking Mars landers.

Studies undertaken to further define minimum time-temperature sterilization specifications (D-values) included determining the heat resistance of naturally occurring bacterial spores; investigating improved pulverizing methods to find out the number of buried organisms in spacecraft components; defining effects of moisture diffusion in spores and their heat resistance; and determining the effectiveness of chemical sporicides for spacecraft hardware.

In addition, studies were initiated to determine the effectiveness of combining heat and low level radiation in the terminal steriliza-

tion of spacecraft. Also, microbiological sampling of Apollo spacecraft at the Kennedy Space Center was increased to maintain the lunar biological inventory and characterize the types of organisms to assist in carrying out the back-contamination quarantine program. A computerized system will make the results of this sampling available more quickly.

### Environmental Biology

Recent studies of light and chemical energy conversion in plants and bacteria have provided space biologists with new information in these fields and yielded data of general interest to scientists. For instance, biochemical analyses of enzymes (which are able to affect growth) in plants orbited aboard Biosatellite II in 1967 showed that the enzyme *peroxidase* was more active in the weightless state. In earth-based research, ultraviolet irradiation decreased peroxidase activity in damaged tissue but increased it in undamaged tissue. Such responses of plants may be the way they adapt and increase their resistance to weightlessness and ultraviolet irradiation in the environment. This enzyme was also very active at extremely low (minus 40°C) and unusually high (100°C) temperatures.

Peroxidase in some unknown way helps regulate ethylene production used to speed up the ripening of apples, bananas, and other fruits. Increased understanding of enzymes like this one could lead to higher crop yields and extend limited growing seasons.

Research on plant photosynthesis showed manganese to be a specific catalyst (or accelerator) required by plants to form and evolve atmospheric oxygen from water. Investigations of how plants are able to adapt to various climates and nutritional environments should provide invaluable information on how they resist cold, heat, pathogens (disease-producing microorganisms or substances), unusual chemical environments, and other factors able to influence their growth. This information will be of value to space technology and is immediately applicable to agriculture, environmental science, and urban planning.

### Behavioral Biology

Scientists have not yet established if physical exercise, intermittent use of centrifuges, or any other method can take the place of gravity during prolonged space missions, nor if constant artificial gravity must be "built into" the spacecraft.

To help answer these questions, the behavior of animals in artificially-produced gravity was under study at the University of Ken-

tucky (*18th* and *19th Semiannual Reports*.) Investigators found that the rodents, birds, and small primates tested at gravity levels above 1 g in the laboratory avoided gravity higher than that on earth. Since gravity ranging from 1 g on earth to weightlessness can be produced only briefly on the ground, the study of its long-duration effects must be carried out in orbiting spacecraft. However, zero gravity can be produced for several minutes in sounding rockets.

Four sounding rocket flight experiments exposed white rats to gravities below and above the earth's for five minutes (*19th Semiannual Report*, p. 57.) The experiments—launched from Wallops Station, Va. December 5, 1967, June 24 and November 21, 1968, and May 15 of this year—marked the first in-flight use of a centrifuge for biological purposes. During the flights the rats were able to select their preferred gravity level in a centrifugally-generated gravity field.

The test animals were fully conditioned by laboratory simulation to the noise, acceleration, spin, and vibration of the rocket at launch before experiencing the weightlessness of flight. They survived the launch and carried out the experiment during the reduced gravity period. Three out of four located themselves close to the level of earth gravity at the end of the five-minute test period.

More flights of this type were planned. The same rocket (an Aerobee 150A) and payload will be used, but there will be up to 20 rats in these more complex experiments.

### Physical Biology

The effects of various physical stresses on ribonucleic and deoxyribonucleic acids—RNA and DNA—in animal bacterial and viral cells were being studied at Pennsylvania State University. (RNA and DNA, complex organic acids, play important roles in protein synthesis and in heredity.) The investigators found that heat caused a rupture of these molecules, which then affected the genetic code. They also discovered that hydrostatic pressure applied to cell components influenced certain temperature-sensitive enzymes—affecting the amount of protein synthesized and reducing DNA synthesis, especially when the cell was under pressure.

Researchers at the University of Maryland discovered that brain cell RNA was reduced in adult rats centrifuged at various speeds to increase the gravitational level and determine the influence on cellular RNA. The extent of RNA reduction depended on the level of the g force and exposure time. The RNA level of these animals eventually returned to normal. When young rats were similarly

exposed, it took three times as long for the same reduction of RNA.

Research at the University of California showed that DNA can exist in various forms, which are controlled by salt and relative humidity. Also, experiments with temperature-sensitive mutant viruses showed that short fragments of DNA, synthesized at increased temperature, became joined when temperature was decreased. A special enzyme (DNA ligase) was found to cause this joining.

## LIGHT And MEDIUM LAUNCH VEHICLES

NASA used Scout, Delta, Agena, and Atlas-Centaur launch vehicles for its unmanned space missions.

### Scout

The Agency was preparing a Scout vehicle to launch the Italian San Marco C spacecraft from the East Coast of Africa late this year or early in 1970. And, as requested by the European Space Research Organization (ESRO), NASA was arranging a Scout launching of the ESRO 1B spacecraft on a reimbursable basis during the latter part of 1969.

In addition, a contract to develop an improved Scout first stage motor was negotiated in June. This motor will perform 30 percent better without an appreciable increase in production unit cost.

### Delta

Delta launched OSO-V on January 22, and the Canadian-American satellite ISIS-I January 30. This vehicle also orbited a fourth Intelsat II on February 5, and later that month the meteorological satellite ESSA IX. On May 21 it placed the third Intelsat III spacecraft in orbit. Two more satellites were launched in June by the Delta vehicle—Explorer XLI (IMP G) and Biosatellite III.

### Agena

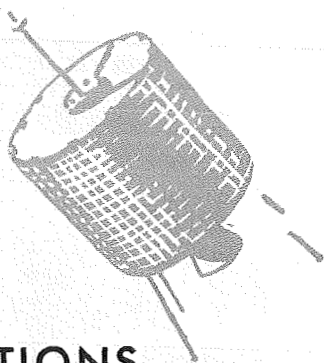
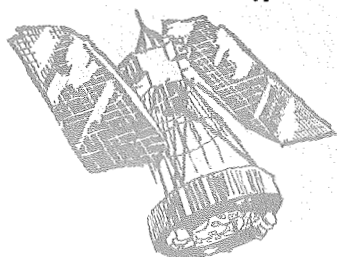
Nimbus III (April 14) and OGO-VI (June 5) were launched by Thorad-Agena vehicles. Also, preparations were underway to launch the Space Electric Rocket Test II this fall and Nimbus D in 1970. (The Nimbus D spacecraft is the last approved mission currently scheduled for a NASA Agena.)

### Atlas-Centaur

In February and March, Atlas-Centaur vehicles injected the two Mariner Mars 1969 planetary spacecraft into Mars transfer orbits. The next Atlas-Centaur flight will be the launching of an Applications Technology Satellite (ATS-E) during the third quarter of the year.

3

## SPACE APPLICATIONS



As evidence of the skill of designers, builders, and launchers of highly complex spacecraft, Nimbus III (replacing Nimbus B destroyed at launch) was orbited in less than 11 months from the time NASA approved its mission. Further proof of this competence was the orbiting of sophisticated satellites of the ESSA and INTELSAT class.

### METEOROLOGICAL SATELLITES

#### ESSA and TIROS

ESSA-IX (TOS-G) was launched by NASA for the Environmental Science Services Administration, ESSA, on February 26 (fig. 3-1.) Its Advanced Vidicon Camera System, AVCS, was providing global cloud pictures to ESSA ground stations at Gilmore Creek, Alaska and Wallops Island, Va. ESSA satellites II, V, VI, VII, and VIII also continued supplying global cloud-cover data through either their Automatic Picture Transmission (APT) or AVCS Systems. TOS-H was in storage and ready to be launched when needed by the National Operational Meteorological Satellite System.

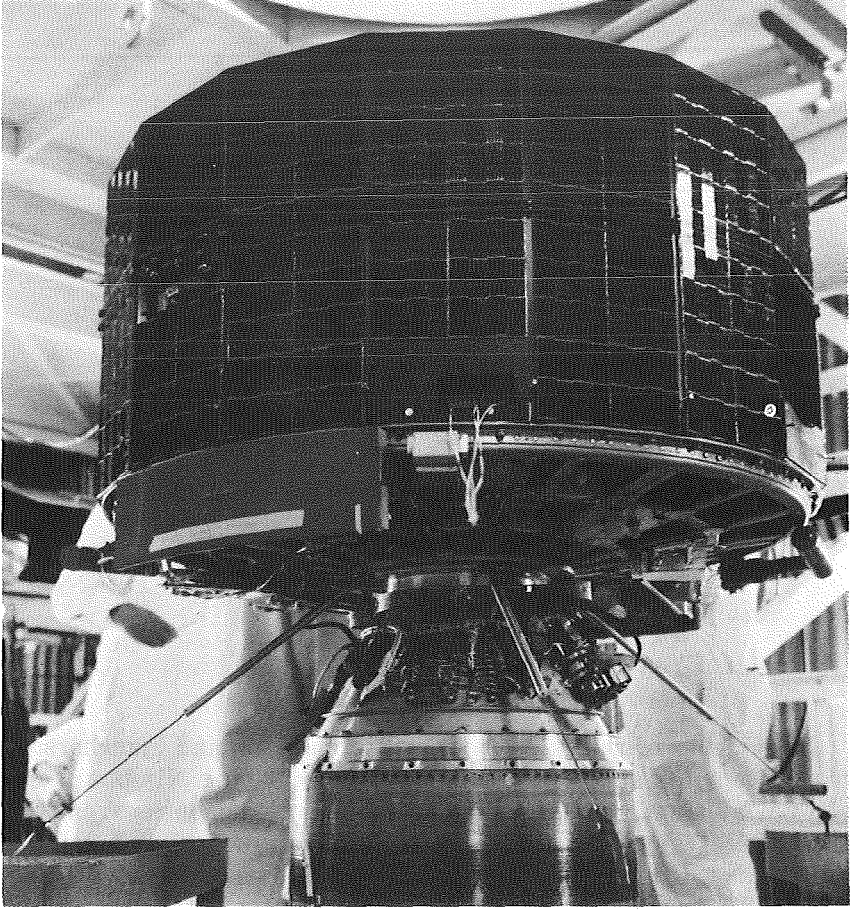


Fig. 3-1. ESSA-IX.

Flight subsystems of TIROS-M were installed in the spacecraft and checked out (*20th Semiannual Report*, p. 79.) Integration and prequalification testing phases of this research and development satellite were almost completed. TIROS-M—scheduled for an October launch—will be the flight prototype for a second series of improved spacecraft of the TIROS Operational Satellite (TOS) class. Five operational spacecraft of this class were being procured to meet ESSA's needs during 1969-71.

#### Synchronous Meteorological Satellite

To satisfy ESSA requirements for continuous observation of the earth's atmosphere on an operational basis in the near future,

initial research and development studies for a geostationary meteorological satellite system were underway. The system, using the Synchronous Meteorological Satellite (SMS), will be managed and operated by ESSA as part of the National Operational Meteorological System. Two operational prototype spacecraft, SMS-A and -B, were planned for development and flight test. Design of the SMS will be based on flight-proven hardware developed either in NASA's research and development program or in similar programs of other Government agencies. It allows day and night viewing.

### Nimbus

Nimbus II was launched on May 15, 1966 and operated for 32 months—far beyond its designed lifetime (*19th and 20th Semianual Reports*.) Nimbus III was placed into a near polar orbit, 676 to 703 miles above the earth, on April 14 of this year (fig. 3-2). An Army geodetic satellite, SECOR (Sequential Collation of Range), carried as a secondary payload on the Agena launch vehicle, was injected into a separate 690-mile circular orbit about 48 minutes after the Nimbus spacecraft separated from Agena. Nimbus and SECOR were operating as planned (fig. 3-3 and 3-4).

The Nimbus III experiments are:

<i>Experiment</i>	<i>Application</i>
Infrared Interferometer Spectrometer (IRIS) -----	Provides vertical temperature profile.
Satellite Infrared Spectrometer (SIRS) --	Do.
Medium Resolution Infrared Radiometer (MRIR) -----	Measures emitted and reflected radiation.
High Resolution Infrared Radiometer (HRIR) -----	Supplies daylight and nighttime cloud cover.
Image Dissector Camera System (IDCS) -	Supplies daylight cloud cover only.
Interrogation, Recording, and Location System (IRLS) -----	Transmits data on wind and other information from platforms.
Monitor of Solar Ultraviolet Energy (MUSE) -----	Investigates upper atmosphere temperature and ozone formation.

The vertical temperature profiles of the atmosphere derived from infrared radiation data measured by the IRIS and SIRS sounding experiments helped to advance meteorology. The temperature data obtained compared favorably with those supplied by local radiosondes. The MRIR provided invaluable information on worldwide distribution of water vapor, carbon dioxide, and strato-

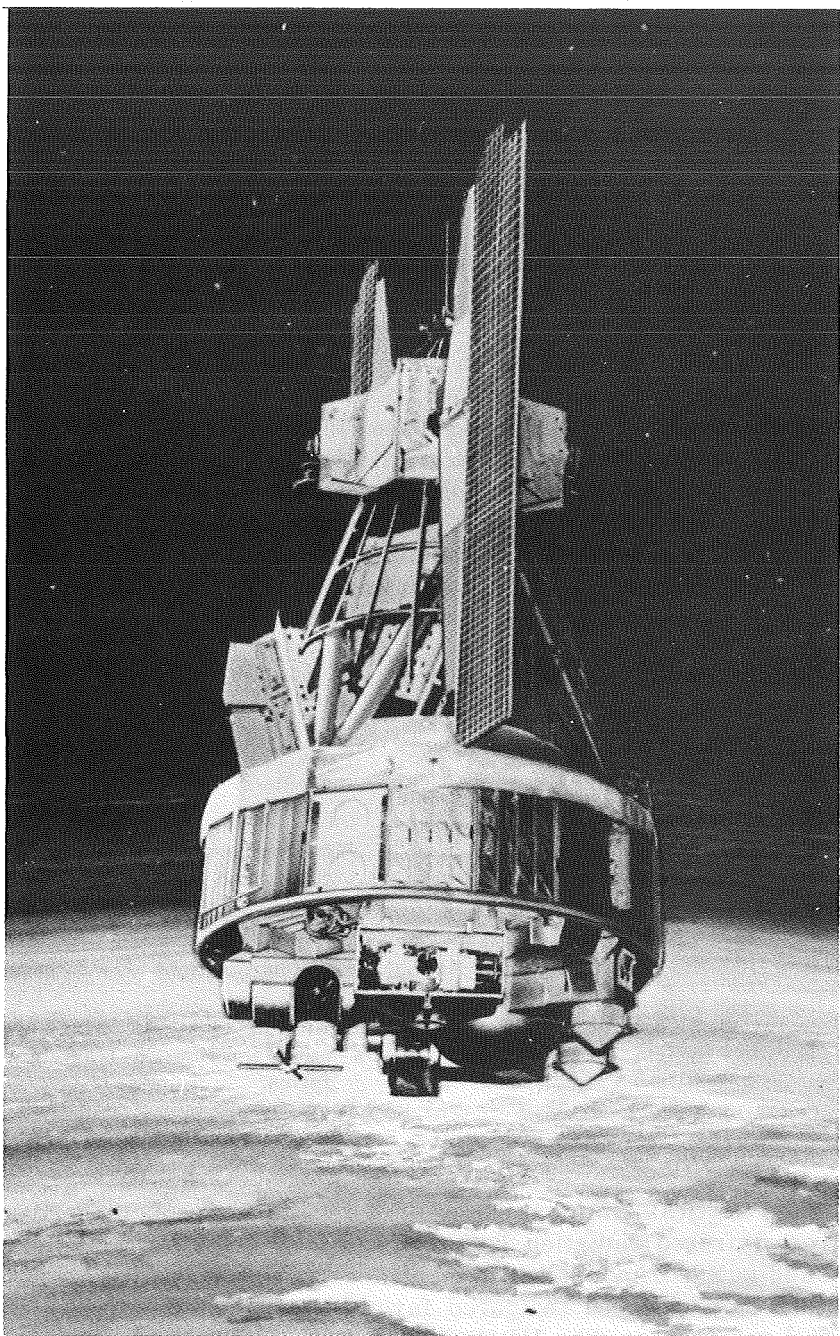


Fig. 3-2. Sketch of Nimbus III in earth orbit.



Fig. 3-3. Nimbus III photograph of Central Africa (April 15).

spheric temperature. (This instrument is similar to the one flown on Nimbus II.)

The HRIR supplied daytime and nighttime global cloud cover photographs (fig. 3-5.). Nighttime data were transmitted to the APT (Automatic Picture Transmission System) stations. Daylight HRIR pictures showed details of the terrain as well as the cloud cover. High quality pictures furnished by the Image Dissector Camera System during the daylight portion of the satellite's orbit

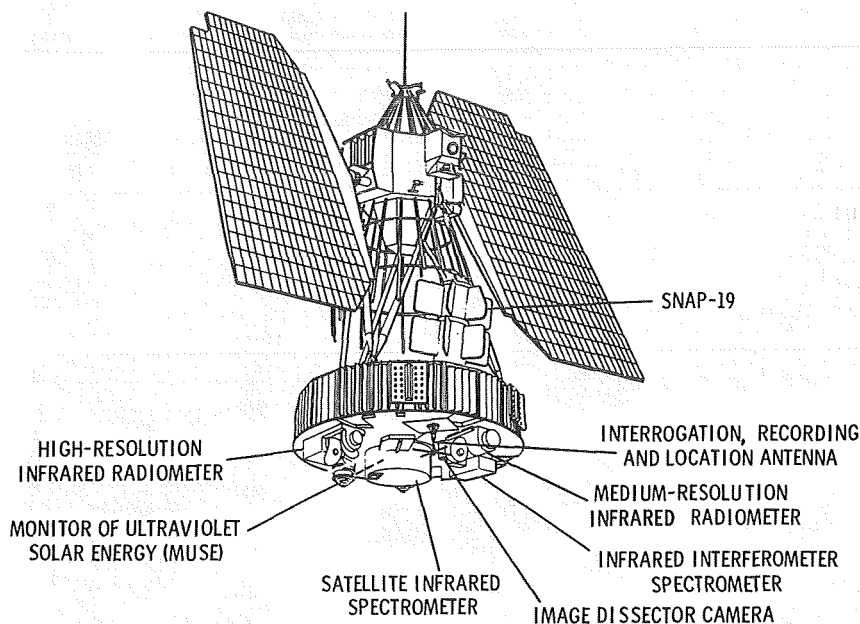


Fig. 3-4. Nimbus III experiments.

were transmitted via the APT system to ground stations around the world.

The Interrogation, Recording, and Location System (fig. 3-6) interrogated platforms at Point Barrow, Alaska; Melbourne, Fla.; Boulder, Colo.; and Goddard Space Flight Center. An IRLS Nimbus D platform was also interrogated at Melbourne, Fla. to demonstrate the compatibility of this system with Nimbus III and D. The Monitor of Ultraviolet Solar Energy experiment continued to measure the solar flux in the area controlling the photochemistry of the ozone region, although two or its five photodiode sensors could no longer provide useful data.

The SNAP-19 radioisotope thermoelectric generator developed by the Atomic Energy Commission performed as designed, producing between 24.4 and 25.5 watts. (*20th Semiannual Report*, p. 80.)

*Nimbus D.*—Nine experiments for Nimbus D were being developed and tested. They include the Image Dissector Camera System as carried aboard Nimbus III, and refined versions of the other five Nimbus III experiments. The three additional experiments, which will use new techniques for making meteorological measurements, are:

- A Backscatter Ultraviolet experiment developed by the National Center for Atmospheric Research and NASA to determine the vertical atmospheric distribution of ozone above 15 miles.

- A Filter Wedge Spectrometer developed at Goddard Space Flight Center to measure water vapor content and its vertical distribution in the atmosphere along a continuous strip about 150 miles wide under the orbital path of the satellite.

- A Selective Chopper Radiometer being developed by the United Kingdom to measure the atmospheric temperature structure between the ground (or highest cloud top) and an altitude of 30 miles.

Nimbus D will have a new control system, but will not use a SNAP-19 power system. It is scheduled to be launched in the spring of 1970.

*Nimbus E and F.*—Plans call for Nimbus E and F spacecraft to be launched in the first half of 1972 and of 1973, respectively. Proposals were received for the Nimbus E experiments, and the flight payload was being selected. The payload for Nimbus F was also being determined. Its experiments will include extension of remote sensing of the earth's atmosphere and surface to use the "windows" and absorption bands in the microwave portion of the electromagnetic spectrum.

#### Meteorological Sounding Rockets

To explore the atmosphere 20 to 60 miles above the earth, NASA launched 39 research sounding rockets of the Nike-Cajun class. Fifteen coordinated grenade firings and two ozone soundings were made from Wallops Station, Va.; Pt. Barrow, Alaska; Ft. Churchill, Canada; and Kiruna, Sweden during minor warmings of the stratosphere in January and February. They were also coordinated with experiments measuring electron density, nitric oxide, and ion composition.

Four grenade type rockets were launched from El Arenosillo, Spain and four from Wallops Station at approximately the same local time in a coordinated series of soundings to compare atmospheric structure and winds, and to study the mesosphere and stratosphere at the two sites, which are at about the same latitude but separated by 70° of longitude. Preliminary analysis of data obtained indicated a maximum temperature difference of 15° C at an altitude of 45 miles.

*Operational Rocket System.*—Progress was made toward developing an inexpensive operational meteorological sounding rocket

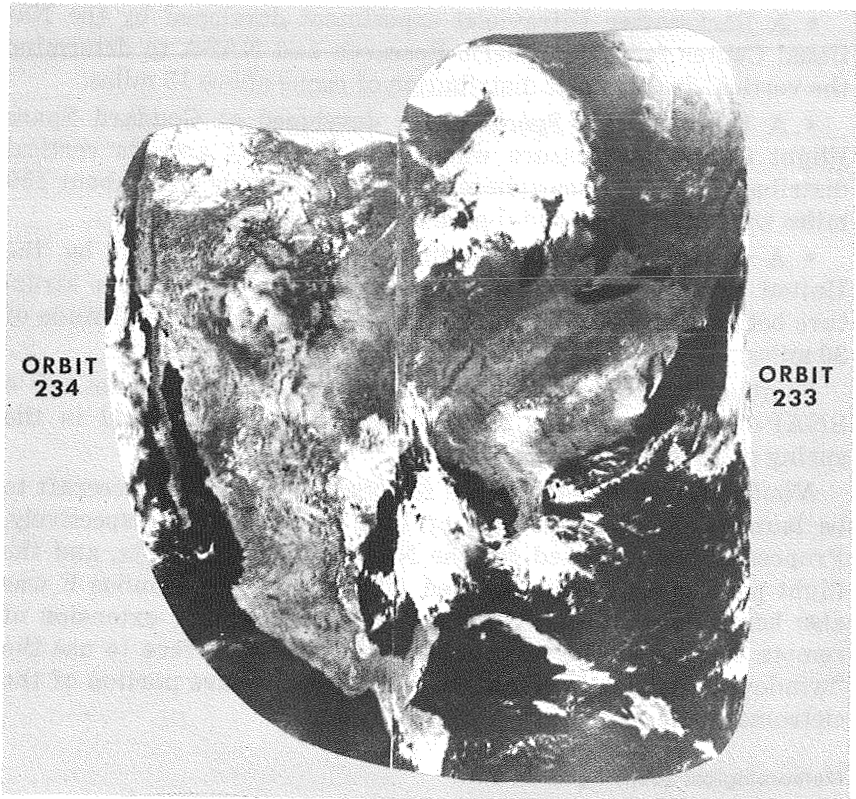


Fig. 3-5. Daylight picture of North America from the Nimbus III HRIR (May 1).

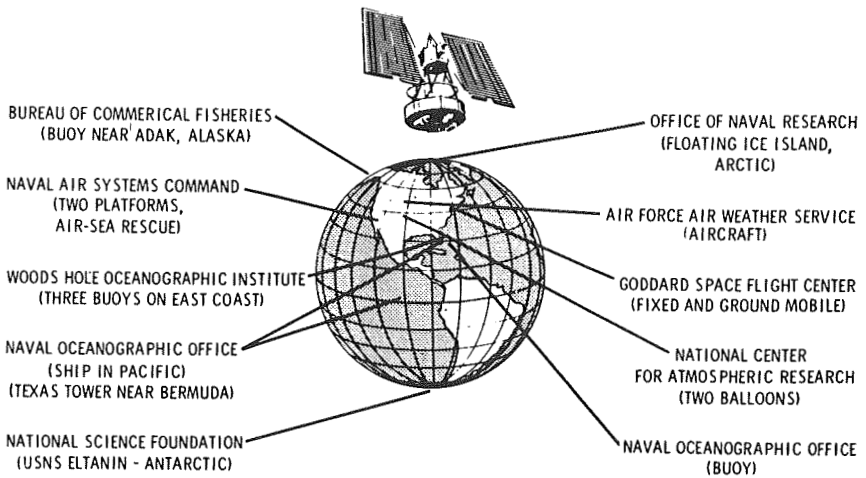


Fig. 3-6. Nimbus III Interrogation, Recording, and Location System platform locations.

system, with the successful spin firing tests of two flight weight rocket motors. A low density flow facility was developed at Langley Research Center capable of simulating the density and velocity encountered by meteorological payloads at altitudes up to 60 miles, and, lightweight telemeters were tested aboard Arcas rockets.

A conceptual design study to determine the most feasible meteorological sounding rocket system was completed. The system, recommended to obtain data to 60 miles, would consist of a combined precise phased array tracking radar, a dual thrust rocket, a one meter passive falling sphere, and chaff. Since the proposed system would require extensive radar research and development, alternative methods were being considered.

## COMMUNICATIONS SATELLITES

### INTELSAT

NASA continued to launch INTELSAT satellites, on a reimbursable basis, for ComSat on behalf of the 68 countries of the International Telecommunications Satellite Consortium (INTELSAT) which owns them. (Fig. 3-7.) Early Bird or INTELSAT I—the first commercial communications satellite (orbited in April 1965 with a planned lifetime of 18 months)—was phased out of service January 18, 1969, after providing continuous service between North America and Western Europe. It was reactivated at the end of June when an INTELSAT III failed over the Atlantic.

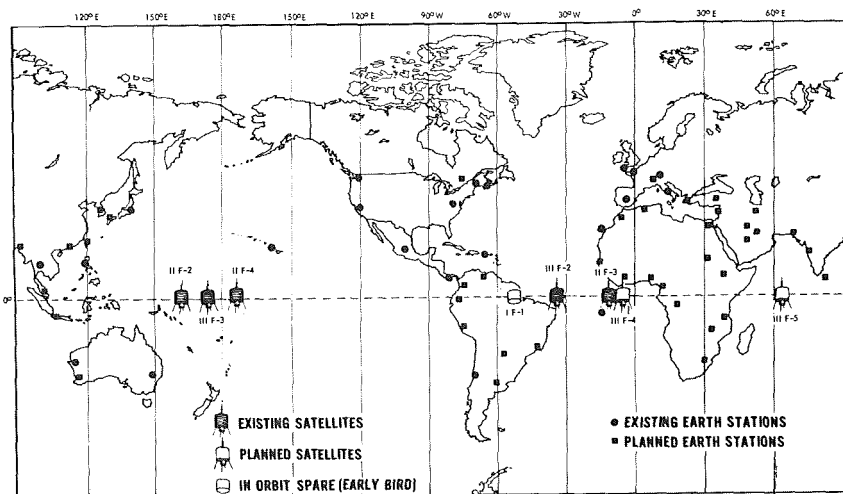


Fig. 3-7. INTELSAT satellites and ground stations as of February 27, 1969.

Three INTELSAT IIs, launched in 1967, designed to operate for three years and able to provide twice the geographical coverage of Early Bird, were in orbit. One was over the Atlantic Ocean and two over the Pacific. (*19th Semiannual Report*, p. 65.) The latest in the INTELSAT II series was launched in February of this year to provide service between North America, Latin America, Western Europe, and Ascension and Grand Canary Islands.

Four of the INTELSAT III satellites will combine for global communications (*20th Semiannual Report*, p. 82.), two over the Atlantic, one over the Pacific, and one over the Indian Ocean. Each will have 1,200 two-way voice channels (INTELSATs I and II were limited to 240 circuits) and be able to operate for five years. The first INTELSAT III failed when a launch vehicle malfunctioned in September 1968, but the next INTELSAT III was successfully launched in December into an orbit over the Atlantic Ocean. The third INTELSAT III was placed in orbit over the Pacific in February 1969. In May, it was moved to the Indian Ocean and replaced by a fourth INTELSAT III launched over the Pacific.

ComSat contracted for four INTELSAT IVs in October 1968, with a first launch planned for early 1971. (*20th Semiannual Report*, p. 83.) Each of these advanced spacecraft will be designed to provide between 3,000 and 10,000 telephone circuits and operate for seven years. Atlas-Centaur was selected as the launch vehicle. Two steerable dish antennas aboard will enable the satellite to focus beams of power at heavily populated areas in North America and Western Europe where communications needs are greatest.

In answer to requests from the Federal Communications Commission and ComSat, NASA provided technical advice on the design and specifications for INTELSAT IV and on INTELSAT III flight worthiness and related problems.

#### NAVIGATION And TRAFFIC CONTROL SATELLITES

In May, the Federal Aviation Administration proposed that a NASA-FAA group be set up to investigate the possibilities of a preoperational UHF aeronautical satellite system for one-ocean aircraft communications and surveillance. The study, to be completed during the last half of this year, would cover satellite location and capability, ground stations, and satellite management requirements. NASA agreed to this investigation and has assembled a study team of scientists and engineers from the Electronics Research Center, Goddard Space Flight Center, and from Headquarters.

### Omega Position Location Experiment

The Omega Position Location Experiment (OPLE) using Applications Technology Satellite III and the Defense Department's Omega navigation system continued position location and data collection experiments (*20th Semiannual Report*, p. 83.) In tests carried out in conjunction with the FAA, aircraft positions were located within two to four miles by using the satellite stationed 22,300 miles above the earth. February OPLE tests conducted in cooperation with the Office of Naval Research located a large fixed buoy in the Bermuda area within  $1\frac{1}{2}$  miles; in addition, oceanographic data from its instruments were transmitted via OPLE to Goddard Space Flight Center.

### APPLICATIONS TECHNOLOGY SATELLITES

Applications Technology Satellites I and III (ATS-I and -III launched December 1966 and November 1967) continued to transmit some data and were providing communications support for Project Apollo. The Environmental Science Services Administration will operate ATS-I for 12 hours daily to carry out meteorological experiments. The spacecraft was stationed over the Pacific Ocean near Hawaii.

ATS-III was moved from  $73^{\circ}$  to  $47^{\circ}$  west to support the Barbados Oceanographic and Meteorological Experiment (BOMEX) of several Federal agencies and research institutions, to photograph hurricanes, and perform experiments for European investigators (*20th Semiannual Report*, p. 84.)

The next Applications Technology Satellite (ATS-E) was being readied for an August launch. Its launching was delayed for three months so that two more experiments might be added to the payload. The first was an L-band aeronautical and a maritime mobile communications and propagation experiment. By comparing the performance of the L-band with that of the VHF band demonstrated with ATS-I and -III, the experiment will help the U.S. plan aircraft-maritime mobile satellite systems. The other experiment was one to investigate solar cell degradation mechanisms whose effect was observed on ATS-I and -III.

An experiment payload was selected for ATS-F and Titan IIIC was designated the launch vehicle for ATS-F and -G, with a first launch scheduled for 1972.\*

### GEODETIC SATELLITES

#### GEOS

Ground stations were still able to track GEOS-I with precision

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\* The ATS-F launch was deferred to 1973, as a result of fiscal year 1971 budgetary decisions.

through its laser corner cube retroreflectors. (*19th and 20th Semiannual Reports.*) Other instruments carried by this satellite, orbited in November 1965, could not be used.

In spite of its reduced power supply, GEOS-II was also operating. The satellite (launched in January 1968) was supporting Air Force camera teams in geodetic observations of South America, helping calibrate selected C-band radar systems, and finding out if the data acquired could be used to position the geodetic stations and measure intersite distances. GEOS-II will also aid in comparing and calibrating laser tracking equipment of NASA and the Smithsonian Astrophysical Observatory set up at the Observatory's Mount Hopkins site in Arizona.

GEOS-C, planned for a 1971 launching, will measure mean sea level and dynamic variations of the ocean's surface, and provide additional data needed to describe the gravity field of the earth.

## PAGEOS

PAGEOS-I, the large passive balloon satellite launched in 1966, continued to supply geodetic data.

## EARTH RESOURCES SURVEY

The interagency Earth Resources Survey Program Review Committee—under the chairmanship of the NASA Associate Administrator for Space Science and Applications—met twice to review program requirements and plans. Technical specifications for requesting proposals for Earth Resources Technology Satellites (ERTS-A and -B) were approved. In addition, the Benefits Subcommittee discussed a detailed cost-benefits study of water management and agriculture, plans were made to establish an International Affairs Subcommittee, and a possible Oceanography Subcommittee was considered.

Committee members (assistant secretaries of the Departments of Interior, Agriculture, Commerce, and Navy) also coordinated their Congressional and Budget Bureau presentations. Observers from the National Council on Marine Resources and Engineering Development, Department of Transportation, Bureau of the Budget, Department of State, and the Department of Defense were invited to attend sessions of interest to them. Further, arrangements were made to include other Federal agencies as regular members of the group as the Earth Resources Survey Program develops.

### Aircraft Program

In the Earth Resources Survey Aircraft Program some flights were made over the North Atlantic to obtain data on sea state and surface temperatures, and others were made to give ESSA support during the Barbados Oceanographic and Meteorological Experiment in the Carribean. Also, Mexican test sites were overflown between April 7 and 22 in accordance with an agreement for this country to assist Mexico in remote sensing of earth resources (p. 157.) Other flights were over Puerto Rico to provide multidisciplinary data in such areas as geology, hydrology (fresh water outflow), underwater shoals, and urban development.

The data acquired by the aircraft program were under study by various Government agencies and academic institutions. Preliminary reports will be prepared within three months after completion of the flights of a mission and final reports published as soon as possible.

Noteworthy accomplishments in the Earth Resources Survey (ERS) Aircraft Program included the following:

- Negotiation of a contract for the development and construction of a multispectral scanner capable of recording the reflectance and radiation of objects throughout the visible and far infrared regions of the spectrum.
- Construction of a module containing cameras and other remote sensors for installation in an aircraft to provide continuous high altitude remote sensor coverage.
- Installation of remote sensors on an aircraft with greater capabilities than the one formerly used.
- Awarding of a contract to develop a passive microwave imager capable of recording signals at the 10.6 GHz level. It will be used to investigate emission characteristics from different regions of the earth's surface.
- Installation of such advanced remote sensors in ERS aircraft as a scatterometer, an infrared imager, a radar imager, and a 5-channel radiometer.

### Earth Resources Technology Satellite

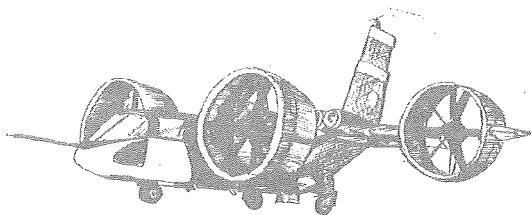
Several studies of the Earth Resources Technology Satellite (ERTS) were completed at Goddard Space Flight Center, as well as the specifications document for ERTS-A and -B mentioned. The document was used in May as the basis for requesting proposals from aerospace industrial contractors for definition-preliminary design of the first two ERTS missions. Five contractors submitted proposals which were being evaluated.

Development of long lead time equipment needed for ERTS continued. Included were the high resolution TV camera (return beam vidicon), a multispectral point scanner, and the wide band video tape recorder. This equipment should to be ready in time for the planned launch of the satellite during the first quarter of 1972.

In addition, NASA and its contractors were planning methods to handle the ERTS data, giving particular attention to a data handling facility and procedures for processing and distributing the information to users.

# 4

## ADVANCED RESEARCH AND TECHNOLOGY



The Office of Advanced Research and Technology is responsible for a broad and complex program which provides the enabling technology for advanced aircraft and space systems. The objectives of the program—to expand knowledge of fundamental aeronautics and space processes; to anticipate needed technology and provide it on time; and to assist others in solving development or operational problems—are served by a great many projects. Their range and variety are indicated by those discussed in the following pages.

### SPACE POWER TECHNOLOGY

#### Solar and Chemical Power

In a program instituted some time ago to improve the charge control of nickel-cadmium space batteries, NASA investigators found that an auxiliary electrode coupled to the cadmium electrode made it possible to determine when the cell approached full charge. Cells equipped with such auxiliary electrodes were developed and put to their first space application in the OAO-II satellite (*20th Semiannual Report*, p. 56). Each battery contains one cell with an auxiliary electrode that permits manual or automatic control of the voltage at which battery charging is stopped. The spacecraft has remained in orbit more than 6 months or twice its guaranteed

life. The longevity of batteries equipped with third electrodes is expected to be substantially better than six months, and they may even have operating lives of 5–10 years.

#### Nuclear Electric Power Research and Technology

Experimental and analytical programs designed to supply data needed for evaluating various advanced nuclear power system concepts were continued.

*Rankine Turbogenerator Technology.*—A detailed metallurgical examination of a three-stage potassium turbine (Fig. 4-1) was completed. The turbine had operated for 1,350 hours with potassium vapor entering dry at 1500–1550°F and exhausting wet with 10–13% potassium moisture content. Results of the examination were inconclusive in revealing whether observed blade damage was due to liquid impact erosion or mechanical abrasion. The turbine was rebladed and the facility restored to operating status for resumed turbine endurance testing.

A full-scale electromagnetic potassium boiler feed pump was fabricated and assembled. It was being installed in a test loop for performance and endurance testing at flow rates, temperatures, and pressures typical of a 300 KWe space power plant.

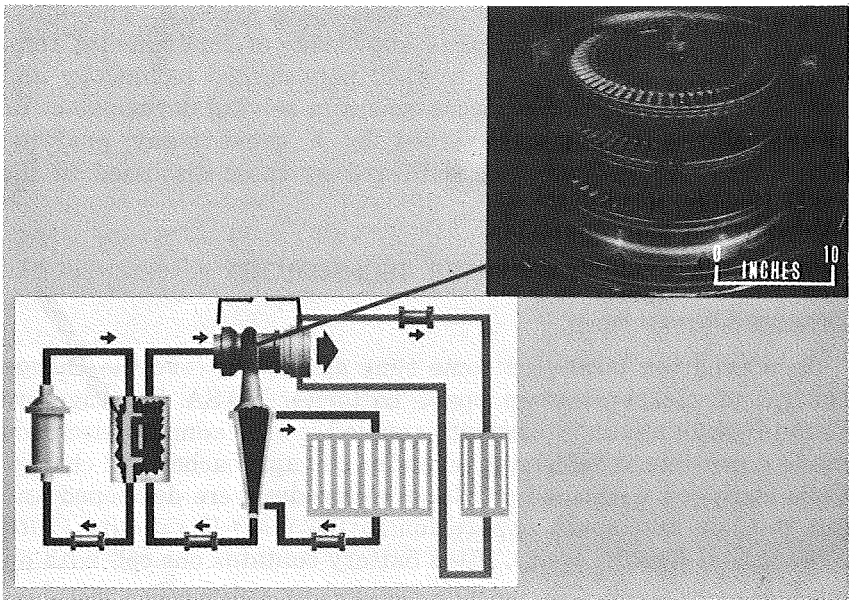


Fig. 4-1. 3-stage turbine.

Most of the major components of the advanced single tube potassium boiler test unit were fabricated, and installation of components in the test facility was started.

Progress continued in the developing and testing of advanced materials (*20th Semiannual Report*, p. 90). The tantalum-base alloy, T-111, corrosion loop logged more than 3,500 hours of continuous operation with pumped two-phase potassium at temperatures to 2150°F; the test is continuing. A creep test of the tantalum-base alloy ASTAR 811-C revealed only one percent creep after 21,000 hours at 2600°F under a stress of 2000 psi. The ASTAR alloy also completed 5,000 hours of corrosion testing in lithium at 2400°F, and a preliminary analysis indicated no corrosion. Advanced developmental versions of ASTAR alloys, containing 13–16 percent tungsten, demonstrated a potential to operate at 250°F higher than ASTAR 811-C under equivalent stress.

High temperature metering and isolation valves constructed of advanced materials completed 5,000 hours of endurance testing at 1900°F in a liquid lithium test loop; detailed examination of the valves was started.

*Thermionic Conversion Technology.*—The thermionic diode kinetics experiment became operational. In this experiment, several electrically heated cylindrical converters are arrayed in series/parallel and cooled by flowing liquid metal at temperatures which would be found in an actual system. Electrical output of the converters is delivered to a DC-DC power conditioner connected to a high voltage resistive load. Electrical heat input is controlled by an on-line analog computer which simulates nuclear reactor dynamic characteristics, thus permitting various control systems to be studied under start-up and transient conditions. Major elements of a typical thermionic reactor system are represented in this pilot plant operation. (Fig. 4-2)

A study was instituted of a thermionic reactor system for unmanned electric propulsion application. Various thermionic reactor concepts capable of producing power levels from 70 KWe to 500 KWe for typical Jupiter orbiter missions will be evaluated, and overall spacecraft designs will be evolved. Another experiment was begun to determine the mechanical effects of sustained electrical breakdown of cracked alumina insulators exposed to cesium vapor and cooled by liquid metal.

Out-of-pile uranium-oxide venting tests were continued. They indicated that “snorkel” tube-type vents may have advantages over “peripheral” vents. Insulator compatibility tests with yttria-stabilized zirconia showed this ceramic to be stable and free of evaporation in contact with tungsten at 1800°C.

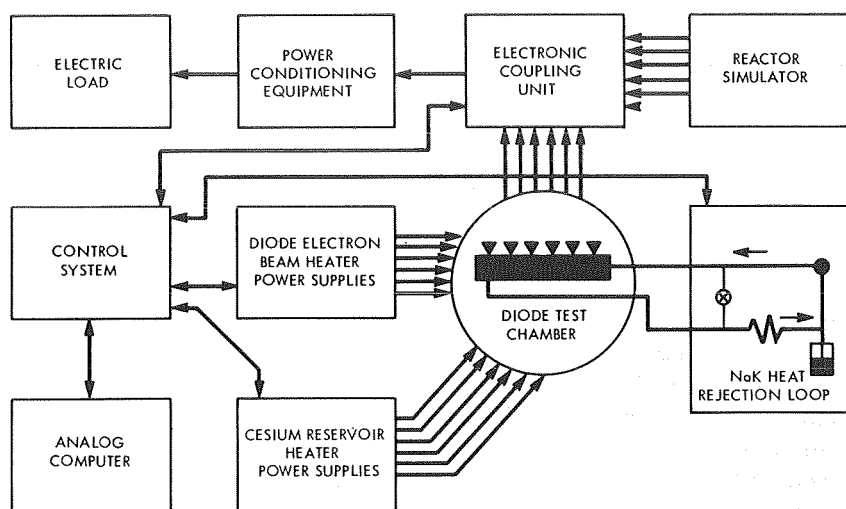


Fig. 4-2. Schematic of thermionic experiment.

Irradiation tests of uranium oxide and uranium carbide fuels continued at the Plum Brook Test Reactor. An out-of-pile cylindrical converter with a duplex tungsten emitter completed more than 20,000 hours of stable operation at 1700°C.

*Low Power Brayton Cycle Equipment.*—Progress was made towards the first test of a Brayton power conversion system employing an electrical heat source. Testing, scheduled to begin during August 1969, will be conducted at the NASA Lewis Research Center's Space Power Facility. Preparatory work included operating a prototype single shaft turbine-alternator-compressor unit mounted on gas bearings under various design conditions for more than 500 test hours, and running performance verification tests on all individual components and subsystems of the power conversion system.

*Isotope Power.*—Two improved SNAP-19 radioisotope thermoelectric generator (RTG) power units (Fig. 4-3) were carried on the Nimbus B-2 which was successfully launched in April. The units are supplying needed supplementary power for the various meteorological sensors. The rate of argon cover gas leakage was higher than the predicted rate and system power was 48.3 watts with both generator systems connected to the spacecraft bus. The power is degrading slowly. Performance of the units is monitored regularly to provide data for use of RTG's in long duration missions.

The SNAP-27 (20th Semiannual Report, p. 93) power system for the Apollo ALSEP was approved for flight by the President.

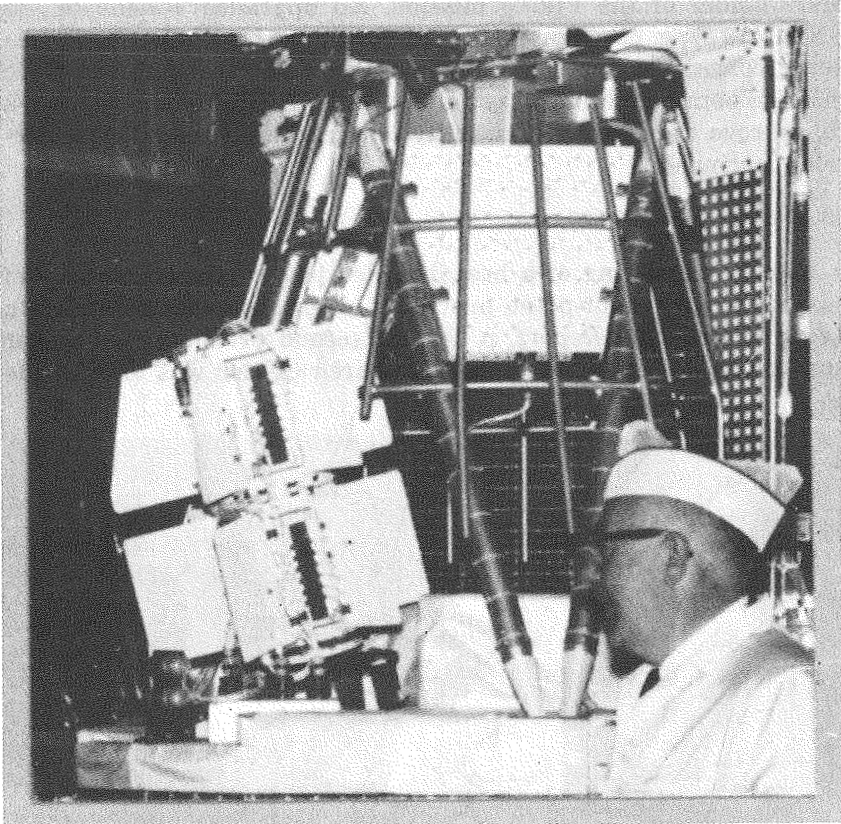


Fig. 4-3. SNAP-19 RTG.

The flight and backup units and equipment, exclusive of the fuel capsules, were delivered in March for storage at Kennedy Space Center. The fuel capsules, stored at AEC's Mound Laboratory, will be delivered to KSC about  $1\frac{1}{2}$  months before the launch date. SNAP 27 will be flown on Apollo 12.

Development of the Apollo Lunar Radioisotope Heaters (ALRH), for use with the Early Apollo Scientific Experiment Package (EASEP), was successfully completed in April, and the heaters were shipped to KSC to be flown on the Apollo 11. (Fig. 4-4) The heaters have also received Presidential approval for flight.

On the basis of mission studies of power for extended space missions and AEC-NASA discussions, it was decided to use RTG's as the power supplies for the Pioneer F and G missions and the Mars lander of the Viking mission. An upgraded version of the SNAP-19 type, based on the design flown on the Nimbus B-2, was being considered for these applications, and arrangements were made to obtain suitable RTG's through the AEC. Technology work to improve the efficiency, stability, and reliability of thermoelectrics continued.

#### SNAP-8 Development Project

Endurance testing of a breadboarded power conversion system passed the 5,000 hour point, providing important experimental data (*20th Semiannual Report*, p. 94). A second breadboarded power conversion system at the Lewis Research Center was used to ob-

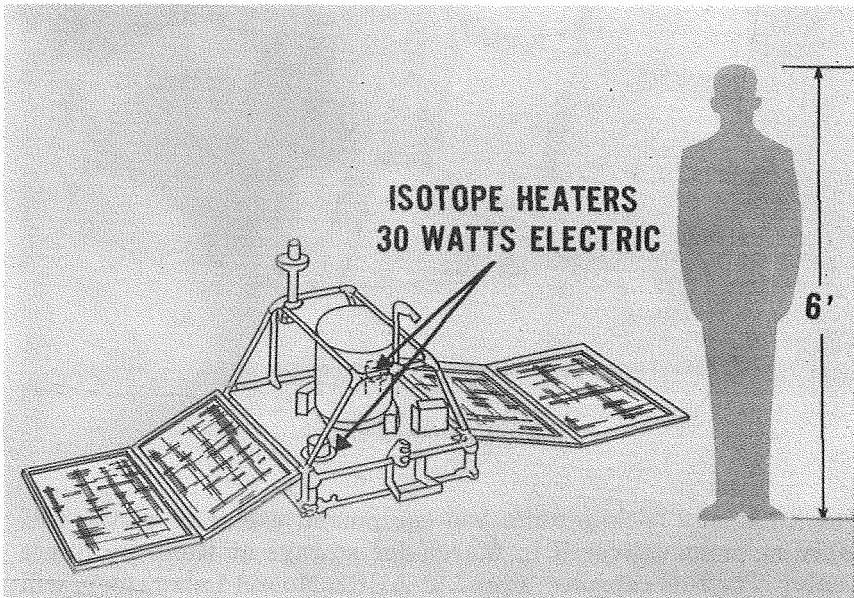


Fig. 4-4. Isotope heaters.

tain information on system dynamic characteristics needed to assure compatibility with the reactor for startup and shutdown.

All major components of the power conversion system have now exceeded 10,000 hours of demonstrated endurance without failure except for the boiler and turbine, which have reached 7,200 and 8,700 hours, respectively, and testing is continuing. Testing of the second SNAP-8 reactor by the Atomic Energy Commission passed the 3,000 hour point.

The development of electric propulsion system technology continued. The advantages of this type of system would be particularly impressive in such applications as auxiliary propulsion for long-term satellite station keeping and primary propulsion for outer planet investigations. (Fig. 4-5)

*Auxiliary Propulsion.*—Progress was made in preparing for the launch of two electric propulsion station keeping systems on the Applications Technology Satellite-E (Fig. 4-6). A 50-micropound-thrust ammonia resistojet of the type which logged over 800 hours of operation on ATS-IV (the first NASA operational use of electric propulsion) and a variable thrust (5 to 20 micropound) contract ion engine experiment were integrated into the ATS-V spacecraft. The latter engine, which provides a capability for electrostatic thrust deflection, was also tested on ATS-IV. Work was also started on bombardment ion engines at the one millipound thrust level.

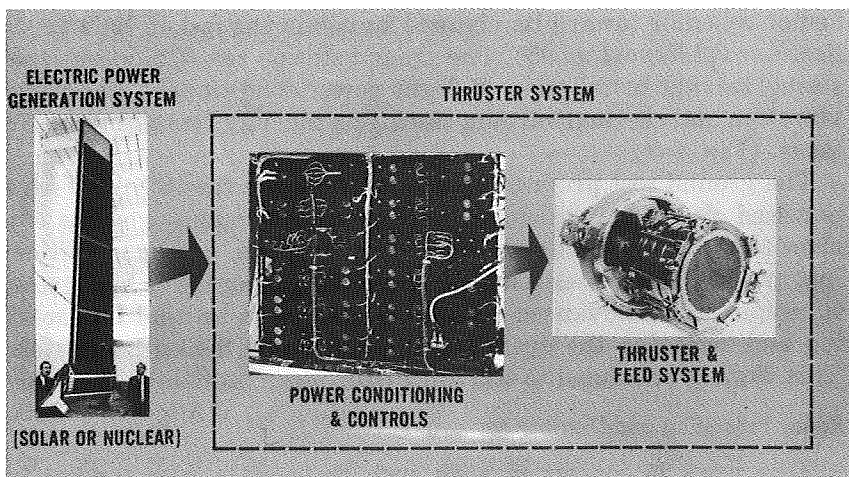


Fig. 4-5. Electric propulsion system components.

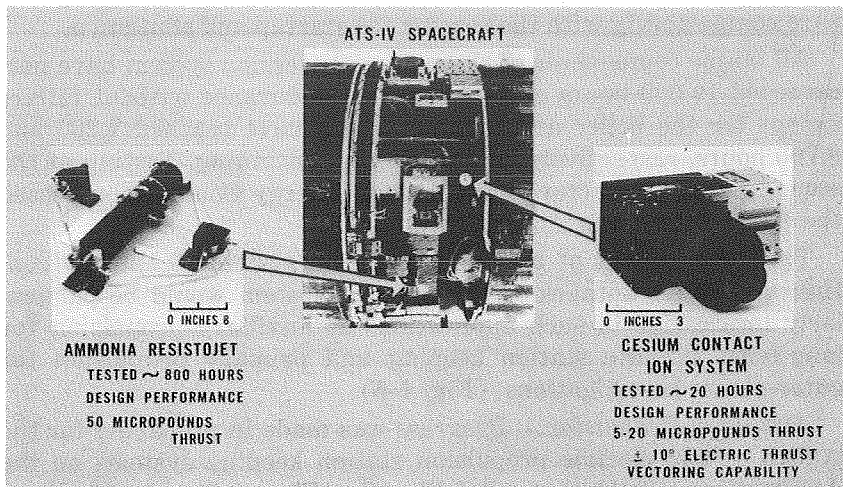


Fig. 4-6. Electric thruster system.

Completion of the planned life tests on high temperature (3600–4000°F), 10 millipound-thrust resistojets was a major milestone. These engines, which have concluded over 8,000 hours operation on ammonia and 6,000 hours on hydrogen, are suitable for the position control requirements of manned space stations. Research continued on resistojets capable of operating on biowastes, such as carbon dioxide, generated by the crew.

*Prime Propulsion.*—The SERT II orbital test spacecraft continued on schedule toward its planned launch in the fall of 1969 (20th Semiannual Report, p. 95). The ground station reached operational status, leaving installation of flight power conditioners, and flight vibration and thermal vacuum testing as the only remaining major tasks. (Fig. 4-7)

The ground test program to demonstrate the feasibility of solar powered electric propulsion also continued to make progress. An open loop test involving the thrusters, gimbals, power conditioning, and switching was completed, and data from it are being used in preparing an advanced closed-loop system to be used for isolating and resolving the operational problems of the entire system. This work is scheduled to start in 1970.

#### Power Processing and Distribution

This work is concerned with such on-board power sources as solar cell-battery systems and isotope thermoelectric and isotope Brayton systems. Research continued on the problems associated

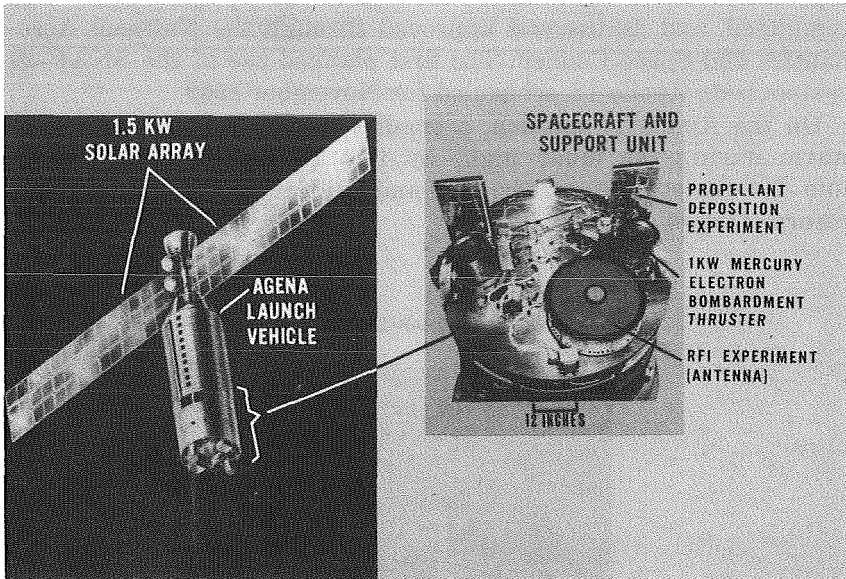


Fig. 4-7. SERT II test.

with processing (conditioning) and distributing the electrical power onboard the spacecraft, and progress was made toward achieving improved reliability and extending solid state power electronics to the multi-kilowatt power level.

The experimental control circuit concept (*17th Semiannual Report*, p. 124) was reduced to practice and a number of microminiature "plug in" devices fabricated. These prototype units will be thoroughly evaluated by various NASA and other users.

An experimental power processor rated at approximately 2 KW was designed, and a breadboard model fabricated at the NASA Electronics Research Center. The unit was then integrated with an ion engine by JPL and tested. It demonstrated a capability to withstand repeated short circuiting of the output caused by the intermittent arcing of the ion engine and an efficiency of 95 percent. When fully developed, this power processor may make it possible to extend single unit capacities to 10 KW or higher. It should also make possible the lightweight units (10 lbs/KW or less), which are particularly important for electrical propulsion applications.

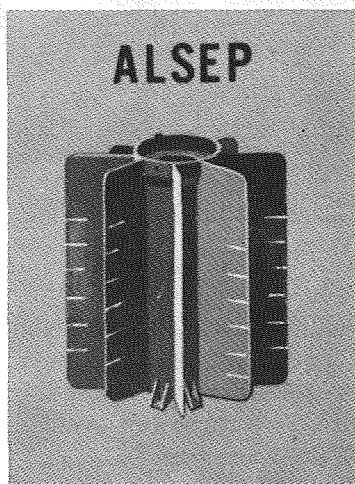
#### Nuclear Flight Safety Evaluation

The interagency nuclear safety review of the SNAP-27 radioiso-

tope thermoelectric generators for use on the Apollo ALSEP was completed, and its use was approved through the National Aeronautics and Space Council. The first planned use of the SNAP-27 system is on Apollo 12, scheduled for November 1969.

On the Apollo 11 mission, a small scientific package was kept warm during the lunar night by two 15-thermal-watt Plutonium-238-fueled heaters, designed and built at AEC's Mound Laboratory. (Fig. 4-8.)

Fig. 4-8. SNAP-27 RTG.



## SPACE VEHICLES PROGRAM

### Meteoroid Protection

Spacecraft resistance to meteoroid penetration is substantially increased by an outer wall known as a bumper—a protective structural sheet placed in front of the principal surface to be protected. (Fig. 4-9) Early tests indicated that when only a small portion of the projectile and front-sheet spray material melts, the penetration resistance increases as the square of the ratio of the sheet spacing to the projectile diameter. More recent tests indicated that when a *considerable* portion of the projectile and front-sheet spray material melts, the penetration resistance increases as the fifth power of the ratio of sheet spacing to the projectile diameter. This information on the effects of sheet spacing will make it possible to reduce the weight of spacecraft walls which are designed to resist meteoroid penetration.

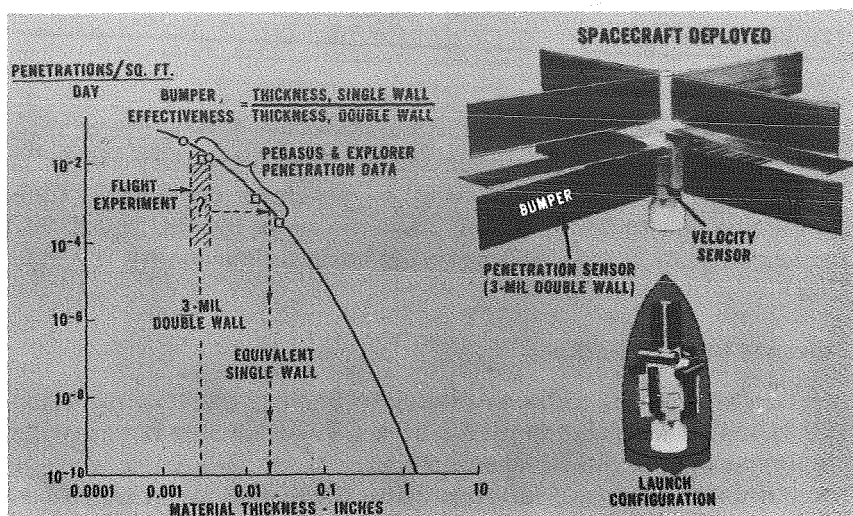


Fig. 4-9. Meteoroid bumper effectiveness.

#### Spacecraft Thermal Control

A method for calculating the shadowing of one spacecraft surface by another was completed and is being used at the Goddard Space Flight Center as a spacecraft thermal design tool. Also, the first of a three-volume compilation of data on the thermal radiative properties of solid materials, which can be used by NASA spacecraft thermal designers, was completed and sent to the publisher.

#### Thermal/Vacuum Test Technology

In research at the Jet Propulsion Laboratory, the Lewis Research Center, and Columbia University, considerable progress was made in developing solar simulator arcs capable of operating at 100KW and above. New electrodes, either cathodes or anodes, which can increase the operational life of such lamps, were developed, and other applications for such high power illumination were investigated.

Two absolute conical radiometers on the two 1969 Mariner Mars vehicles, which are pointed toward the sun, provided the first direct measurement of the solar constant in space. Their data confirmed a value of the solar constant,  $1.95 \text{ cal/cm}^2/\text{min}$ , for energy received at the earth's mean solar distance. This value is the one recently obtained from X-15 and jet aircraft operations. Short

term variations in solar energy output, which were also observed, are being studied.

#### Lifting-Body Flight Program

Since the last report, the HL-10 made seven flights, five of them powered, achieving a maximum speed of approximately Mach 1.4. The vehicle performed well, and no problems developed. Three pilots, two new to the program, made the seven flights. The X-24A made two glide flights and provided basic flying quality information.

#### Advanced Gliding Parachutes

The second phase of the parawing technology program was completed with the 20th test flight of a 5,000-square-foot parawing. Deployment and gliding characteristics of the parawing were determined for payloads ranging up to 6,000 pounds at conditions simulating operational use of parawings with 15,000-pound payloads.

#### Advanced Decelerator Concepts

The final test of a three-test series to investigate flight performance of supersonic parachutes suitable for use in planetary entry and landing was completed. The 40-foot ringsail parachute was carried to test altitude of approximately 33 miles and a speed of Mach 2.9 by a three-stage rocket vehicle. Drag and stability of the parachute were determined by means of load sensors and motion picture cameras, and both the parachute and test payload were recovered in good shape.

#### Lunar Shelter Technology

Plans for lunar exploration indicate that a portable life support shelter will be needed as a base for astronauts for periods of 14 days or more. It would accommodate 2 or 3 men, providing living quarters, work space, supplies for recharging portable life support systems, and a communications center. All these functions require more volume and life support capability than is available in the LM. However, space for them can be obtained from a structure which is packaged for delivery and expanded for use. The basic technology for such a structure has been developed over the past five years. This technology base can now be expanded and developed to provide the structures and materials for this specific requirement. (Fig. 4-10)

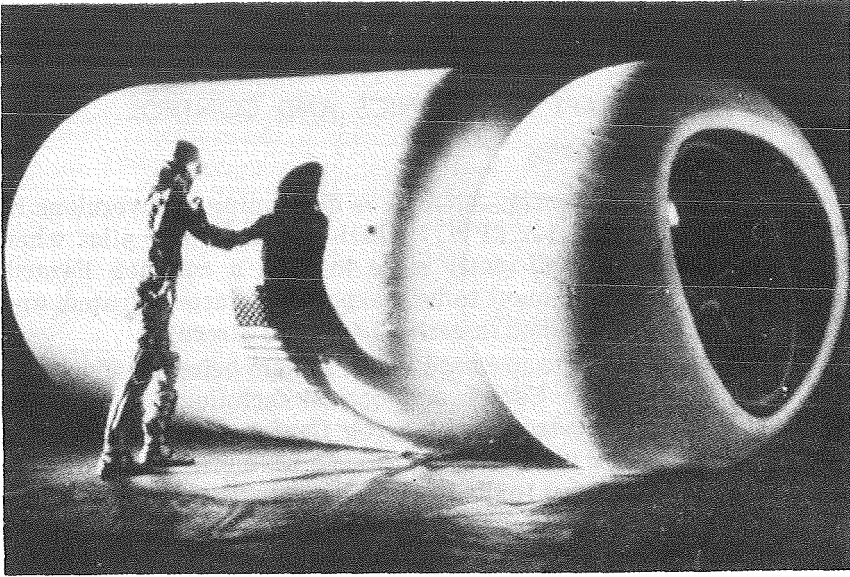


Fig. 4-10. Lunar shelter.

#### Thermal Flutter of Flexible Booms

On the OGO-4 flight, the 60-foot antenna boom began to oscillate shortly after it was deployed. The magnitude of the oscillation was sufficient to cause the satellite to oscillate, and this, in turn, caused the attitude control system to react during each oscillation. The result was an excessive use of fuel.

Goddard Space Flight Center (GSFC) postulated that the solar thermal radiation was causing the oscillation, and Ames Research Center (ARC) tested a similar type of boom in the laboratory and duplicated the oscillation by imposing a thermal environment on the boom. ARC developed a mathematical model, performed experiments to validate the theory, and found that thermal flutter can be predicted. GSFC made several design changes in later booms to reduce thermoelastic effects, and spacecraft employing newly designed booms showed much improved flight characteristics.

#### Space Vehicle Design Criteria

As part of a continuing publications program, NASA issued a number of guides to design during this period (these SP's are listed in appendix N). Prepared by technical specialists from NASA and other government agencies, industry, and universities who collect and assess current information on the design, test, and

operation of space vehicles, these documents serve as design criteria for NASA and the aerospace community.

## SPACECRAFT ELECTRONICS AND CONTROL

### Communications and Tracking

*Pilot Warning Indicator.*—NASA is developing two versions of a pilot warning indicator (PWI) which will inform a pilot when another aircraft is sufficiently close to pose a collision hazard. Plans call for the equipment to be inexpensive, uncomplicated, and light enough to be installed in general aviation aircraft.

Microwave techniques are used in the system being developed by the Langley Research Center and optical techniques in the one developed by the Electronics Research Center (ERC). Although neither achieves the ultimate goal of such systems—that no cooperative device be needed in the intruding aircraft—both are practical and can be built and placed in use in the near future. Flight tests on the microwave system commenced in the summer of 1969; the optical system is scheduled for flight test in 1970. Work will also continue to develop a system which does not require equipment in the intruding aircraft. (Fig. 4-11)

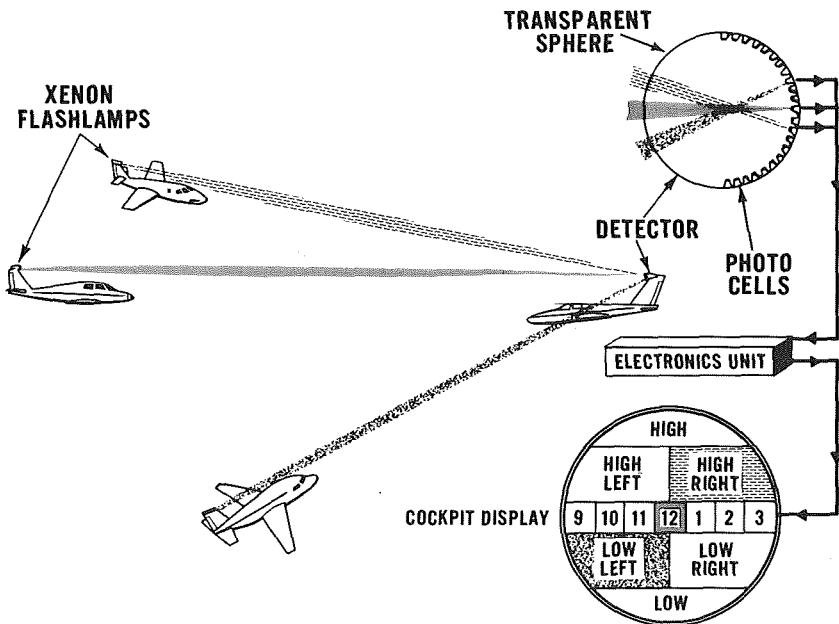


Fig. 4-11. Optical pilot warning system concept.

*Active Optics Technology.*—Intensive work at NASA Centers, to develop an “active optics” space telescope system, resulted in the successful testing of the laser sensing device—one of the critical elements in active optics—of a prototype, light-weight, 30-inch-diameter thin mirror (*20th Semiannual Report*, p. 98). In June, the total system, including the complete servo loop and the actuators, was demonstrated by the contractor. Work was scheduled to continue at the Electronics Research Center to refine the techniques and technology and to build space qualified components of the active optics system.

#### Attitude Control

A precision, fluidic attitude control system was developed for application to sounding rocket research vehicles. A prototype of the system, which was conceived at the Ames Research Center, was developed and built by a contractor. This system should fulfill the need for economical and precise control systems for expendable vehicles which are used in large numbers on research programs.

Laboratory tests and analyses indicated that the system can achieve a pointing accuracy of 0.1 arc seconds and rates as low as 3 arc seconds per second. In developing this system, a fluidic vortex sensor was designed into the thruster systems, changing the performance characteristic from an “on-off” type control to proportional control. Plans call for further investigation of the system for possible use in other NASA space missions.

#### Guidance and Navigation

Computers can be programmed directly by using their own coding structure or by using a higher order programming language which can be translated to the coding structure of a specific computer by another computer. Aerospace guidance and control computers which must operate in real time, require an efficient coding structure (one with the least number of instructions) to conserve operating time. Current programming languages are not efficient in this sense because they make programming the computer easier by employing additional instructions in the final machine language.

A more efficient programming language was developed by the ERC in conjunction with the Air Force. Called CLASP (*Computer Language for Aeronautics and Space Programming*), it enables aerospace computers to be programmed in a higher order language. This language saves 2 to 5 times the previous programming time, reduces checkout and modification time, and produces a

machine language code which will operate in real time with a conventional computer. CLASP is also being considered for space flight application.

*Avionic Systems.*—The ERC developed a computer model, or simulation of typical air traffic control situations, to test avionic systems by simulating the total air traffic environment on the ground. Collision avoidance, flight control, and approach and landing systems were tried with the model and the results applied to the design of the avionic systems.

The ERC also developed an improvement to the aircraft equipment for the standard instrument landing system (ILS) by using inertial navigation along with it. Simulation tests showed significant improvements in touchdown accuracy when a conventional jet transport was flown with the combined Inertial System/ILS (Fig. 4-12). Flight tests to prove the results, scheduled to start in January 1970, will be conducted jointly with the FAA using an FAA aircraft. If the flight tests are successful, the technology will be made available to commercial aviation and should allow air carriers equipped with this device to operate in lower weather minimums than now possible.

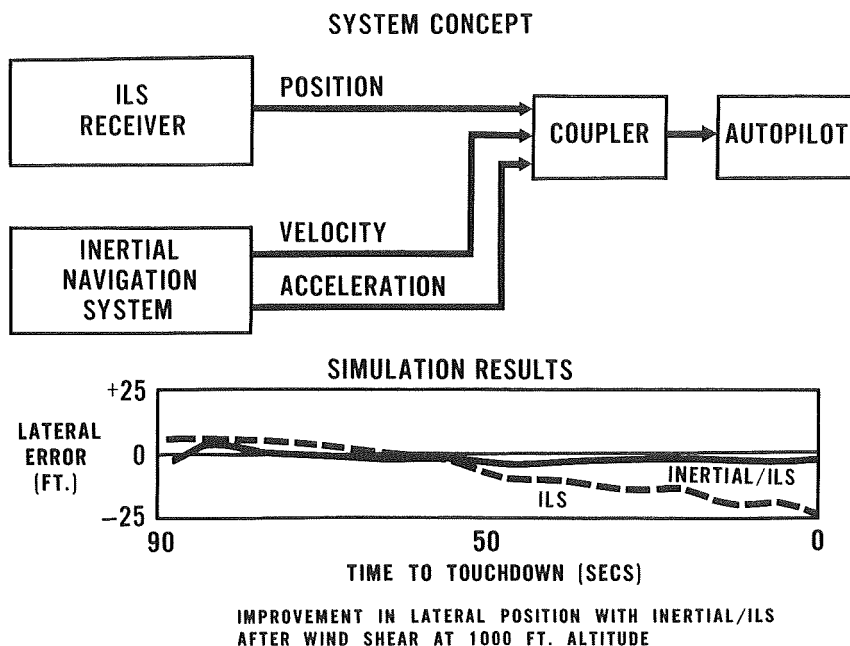


Fig. 4-12. Improved ILS.

## Instrumentation

*Self-Tuning Bandpass Filter.*—Bandpass filters are commonly used to obtain a high signal-to-noise ratio in instrumentation systems. In applications where the signal frequency is variable, Ames designed and built a self-tuning filter which automatically adjusts its center frequency to the signal frequency. This technique permits the use of a filter whose bandwidth is considerably less than the range of frequencies over which the signal may vary. It helps solve a problem by eliminating the use of wide-band filters to avoid signal attenuation thus providing a considerable improvement in filtering effectiveness.

The filter covers the range from 2 kHz to 20 kHz, with constant bandwidth and center frequency gain, and it can be easily converted to cover other decades of frequency. The circuit can also be used to phase-shift a signal by a fixed amount, independent of frequency, and with no change in amplitude as the frequency is changed. The circuit has been used by Ames to improve the measuring range of the vibrating diaphragm pressure system for measuring planetary atmospheric profiles. It should also have many applications in electronic systems.

*Radiometer for Space Applications.*—Another Ames development is a solid state radiometer with a useful spectral range from the UV to the near IR (2,000—10,000 Å). Its small size (2.5 cm<sup>3</sup>), lightweight (14g), and low power (80mW) make this instrument suitable for space radiation measurement experiments, particularly since an improved sensor, a photo diode, and a logarithmic amplifier have increased its performance significantly. The radiometer has a dynamic range of 5 decades, a response time of 1 millisecond at intensities of  $10^{-10}$  W, and it also responds to DC signals, thus eliminating the need for a mechanical light chopper (no moving parts). It will be particularly useful for measuring selected narrow portions of the spectrum over a wide range of intensities, such as for Earth Resource Surveys.

## Data Processing

*Self-Learning Machine Techniques.*—In research at ERC, investigators demonstrated the feasibility of designing “self-learning” machines which can “teach” themselves to recognize and classify events or patterns in large masses of data without human assistance. Preliminary mathematical modeling of the new self-learning technique indicated that it is superior to pattern recognition methods which depend upon “supervised learning” techniques. Super-

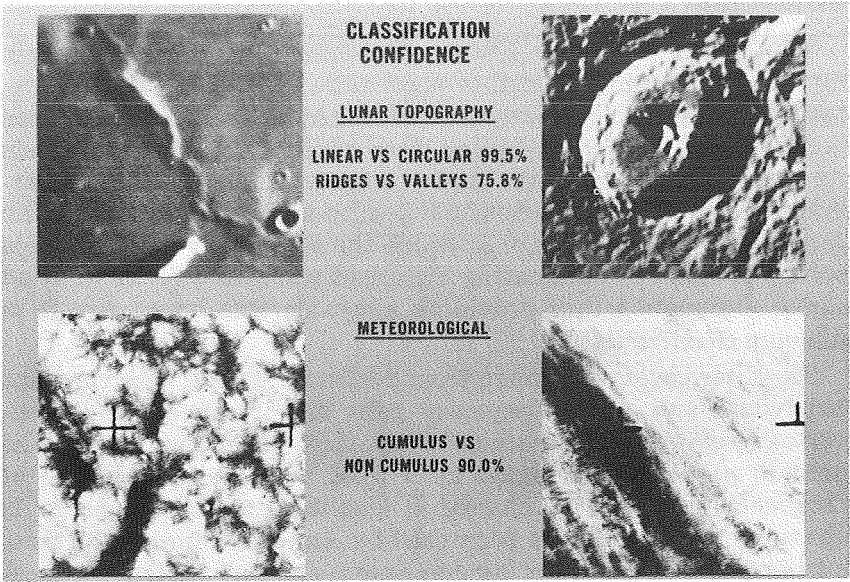


Fig. 4-13. Confidence factor achieved in laboratory recognition of features.

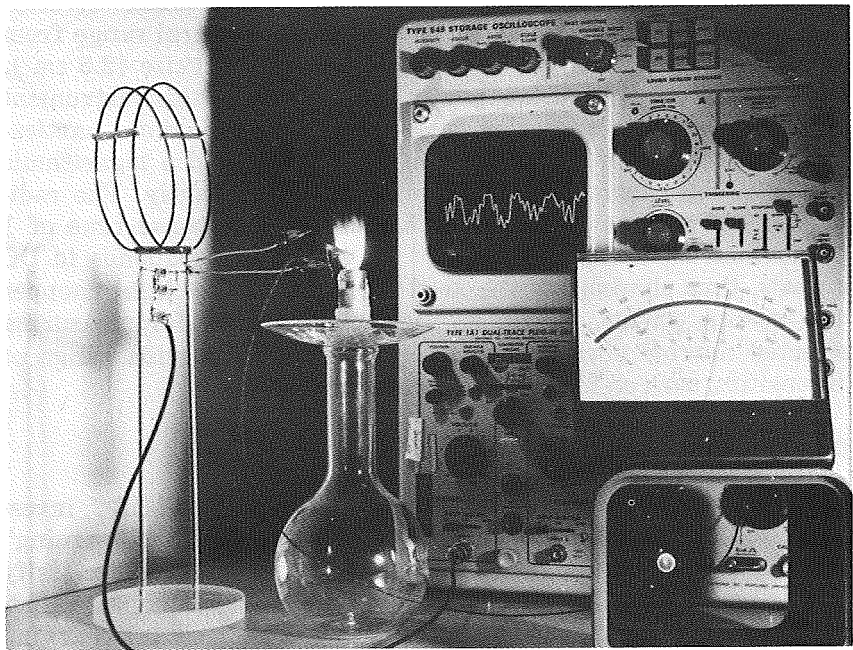


Fig. 4-14. Silicon carbide backward diode.

vised learning requires *a priori* assumptions by a human operator of the characteristics of the data to be analysed and the number and statistical nature of differing patterns which might be in the data, e.g., objects in a photograph. The self-learning technique eliminates the need for prior knowledge or assumption of data characteristics. Computer simulations achieved an average of 80 percent success in classifying cloud types present in a random selection of Nimbus meteorological photographs. For the two types of clouds shown, a score of 90% was achieved. (Fig. 4-13) Such machines would be particularly advantageous in planetary exploration where data characteristics in an unknown environment cannot be exactly specified in advance.

#### Electronic Components

In its continuing program to improve component performance, the ERC developed a silicon carbide backward diode for use as an RF detector in communication and tracking systems and demonstrated its operation at temperatures up to 1300°F. (Fig. 4-14) This device which is more rugged than commercially available diodes, operates over a wider frequency range, and is less subject to burnout due to overloading, is especially useful in electronic systems required to operate in extreme high temperature environments as in solar and inner planet missions.

Another component developed for ERC is a Metal Nitride Oxide Semiconductor (MNOS), variable threshold, memory transistor. This device has such desirable characteristics as high operating speeds, low drive power, non-volatility, and improved radiation resistance. It can be used in most circuit applications involving memory such as adaptive systems, logic circuits, and computers and is compatible in size and fabrication procedures with current integrated circuit technology.

### AERONAUTICAL RESEARCH

#### Aircraft Aerodynamics

A wind-tunnel investigation was undertaken to determine aerodynamic characteristics of a double-delta wing supersonic transport configuration with an aspect ratio 1.66. Ground effects were also investigated.

Calculations showed that the takeoff distance could be reduced by increasing the speed beyond that corresponding to the ground limit value of angle of attack. It was also found that the lift-drag ratio in the takeoff climb could be improved by accelerating after

lift-off, because the speed for maximum L/D is about 250 knots relative to a takeoff speed of about 190 knots. The improved L/D results in more efficient flight and reduces noise at distances greater than three miles from brake release.

An experimental program on cruciform wing-bodies was extended to cover Mach numbers from 1.50 to 4.63. Wind-tunnel tests were made to determine the longitudinal and lateral aerodynamic characteristics of a cruciform wing-body missile configuration with various wing planforms. The planforms included a family of delta wings and a family of rectangular wings having a constant root chord but varying spans. In addition, a cranked-tip planform was included, and some limited tests were made to determine the longitudinal location effects for a rectangular wing.

The results, summarized as a function of Mach number, are useful in demonstrating the importance of certain parameters, and as a source of systematic experimental data for future correlation with analytical techniques.

In another area, a two-dimensional experiment and theoretical investigation were conducted on an NACA airfoil (65<sub>1</sub>-213) to determine the effect of Reynolds number and transition location on shock-induced separated flow. The experimental investigation was carried out at Mach numbers from 0.60 to 0.80, angles of attack from 0° to 4°, and Reynolds numbers from  $3.0 \times 10^6$  to  $16.8 \times 10^6$ . Transition locations from 0.05 to 0.50 chord were utilized.

The results indicated that variation of the Reynolds number from full-scale values to the usual wind-tunnel values results in substantial changes in the shock location, trailing-edge pressure recovery, and boundary-layer losses at the trailing edge. By properly fixing the boundary-layer transition point on the wind-tunnel model, full-scale flows can be simulated at the usual wind-tunnel Reynolds numbers. The required location of the transition point can be determined with acceptable accuracy by simulating the full-scale boundary-layer thickness at the airfoil trailing edge.

Further research on sonic boom produced a design method whereby the volume of a body may be continually increased without increasing the maximum overpressure or impulse. A sequence of three sonic-boom generating bodies having length ratios of 1:2.5:4 and volume ratios of 1:7.6:16.6 was designed and tested. The results, together with theoretical considerations, indicated the essential signature characteristics (maximum overpressure and impulse) in the far field to be virtually the same for all three bodies.

## Aircraft Structures

The flutter of stressed skin panels in supersonic flow was investigated, and a theoretical solution, which included representation of both structural and aerodynamic damping, predicted experimental results with reasonable accuracy. This should reduce the reliance on empirical procedures necessitated by the inadequacy of earlier theories in predicting flutter, particularly for panels subjected to near-buckling compressive loads.

In a study of the design and cost aspects of light airplanes, a wide variety of structural materials and concepts, presently and potentially available, were evaluated. Conventional aluminum sheet metal structure was determined to be the most economical, but significant cost savings were foreseen with composite structures using projected advances in materials and fabrication processes.

A quasi-steady flutter analysis technique was evaluated at hypersonic speeds. Static forces and moments were measured in a wind tunnel for airfoils having various planforms and sections, and a flutter analysis was formulated for these airfoils in terms of the measured aerodynamic quantities. The flutter solutions agreed reasonably well with those determined experimentally.

Existing methods for calculating elastoplastic stress-strain conditions at notch roots under cyclic loading were investigated. Steel and aluminum notched sheet specimens with various stress concentration factors were studied for several levels of constant amplitude reversed loading. The cyclic stresses and strains measured at the notch roots correlated closely with those calculated on the basis of existing theory.

## Air Breathing Propulsion

In conjunction with studies of supersonic inlet performance, an investigation was begun of the effects of non-uniform and turbulent inlet flow fields on the operation of the engine fan and/or compressor. A system was installed in the duct upstream of the engine to create steady state distortions and coherent pressure oscillations representative of the flow from a supersonic inlet. In addition, a turbofan engine, of the type used in the F-111 airplane, was equipped with high response instrumentation to investigate the origin of compressor stall and to trace the progression of stall through the engine. This work should provide data for advanced fan and compressor designs and operating procedures with increased stall tolerance and high performance at supersonic flight conditions.

### General Aviation Aircraft

Full-scale wind tunnel tests of a typical single engine light airplane, the third of its class, were completed in the 30- x 60-foot subsonic wind tunnel at Langley Research Center (Fig. 4-15). The basic aerodynamic and static stability data obtained showed usual behavior for the configuration tested, with good stalling characteristics and generous control margins for all flight conditions. A technical note on this work is being prepared. (Fig. 4-16)

### V/STOL Aircraft

*Rotorcraft.*—Widespread commercial use of helicopters in heavily populated areas has resulted in the need for a better understanding of the lifting rotor-propeller as a noise source. Such an understanding is a prerequisite to reducing noise by modifying the basic elements which produce the noise. The first step is to develop an acceptable method of predicting the sound pressure level versus frequency as a basis for investigating ways to reduce the noise level. NASA, therefore, contracted for a study to develop a method whereby both the rotational and vortex shedding effects are properly accounted for in predicting the noise generated by a lifting rotor.

The chief findings of the study were that: inclusion of vortex shedding effects in addition to the rotational effects significantly improved the prediction of the measured noise levels over that

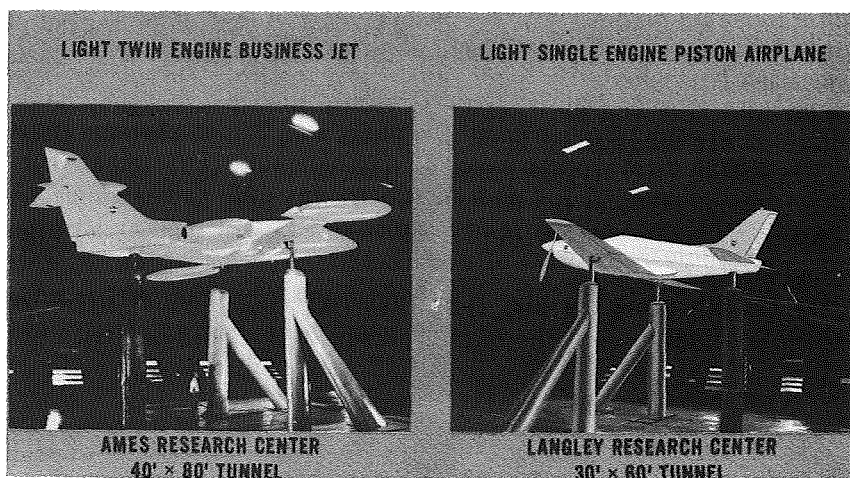


Fig. 4-15. Light airplane in wind tunnel.



Fig. 4-16. Representative general aviation aircraft.

which considered only the latter; “blade slap” characteristics are most readily observed and thus investigated by using pressure time history plots.

Most proposed composite-lift vehicles, which combine the high hovering efficiency of the helicopter with the high cruise efficiency of fixed-wing aircraft, are based on independent lift systems where attempts are made to optimize the hover and cruise systems independently. One concept, however, called the “rotor/wing” combines the hover and cruise systems into a single lifting surface in an attempt to reduce the weight penalty associated with independent systems. For the helicopter flight mode, a three-bladed lifting surface rotates; for the airplane cruise flight mode, the lifting surface is stopped and becomes a fixed wing.

To provide general information on the characteristics of the rotor/wing aircraft, an investigation was undertaken in the Langley full-scale tunnel on three different rotor/wing configurations. Aerodynamic and control characteristics data were obtained for helicopter flight conditions, and cruise aerodynamics data were obtained for airplane flight conditions. Only small differences were found in the three configurations for most of the helicopter-mode operating conditions. Need for improvements in blade design was indicated, and a potential roll control problem at high tip-speed ratios was identified. The airplane-mode cruise investigation results indicated that careful design of composite lifting surfaces

was essential in order to achieve good efficiency in both rotary-wing and fixed-wing flight.

Another part of the study examined the aircraft dynamic characteristics of a rotor/wing aircraft during conversion from wing borne to rotor-borne flight. It was found that the principal problem associated with the conversion is the possibility of a large attitude disturbance during the first revolution of the rotor. The disturbance is due to an oscillation of the lift center of pressure in a longitudinal and lateral direction at a frequency equal to the number of blades multiplied by the rotor rotational speed. The wind-tunnel study indicated that large-amplitude cyclic pitch is one means of eliminating the source of the aircraft disturbance for a three-bladed rotor/wing aircraft; in addition, four blades on a rotor-wing aircraft may so substantially reduce the disturbing moments that cyclic pitch is not required to eliminate them.

Related analytical investigations indicated that the disturbance may also be reduced in magnitude by a rapid initial rotor acceleration or by using an oscillation of the horizontal tail surfaces at the frequency of the lift center-of-pressure oscillation.

*Jet VTOL Aircraft.*—When jet VTOL aircraft operate at low speeds, they can no longer rely on the conventional aerodynamic control surfaces to produce adequate control moments, but must use propulsive control devices. One suitable type is the jet reaction control system which uses high-pressure air bled from the engine. The bleed air is ducted to nozzles at the nose, tail, and wing tips, and by controlling the flow of bleed air through these nozzles, the pilot can produce control moments as required.

In designing the jet reaction control system, it is necessary to see that the amount of bleed air available for control is adequate to provide satisfactory handling qualities; the engine and reaction control system must therefore be designed to meet this bleed-air requirement. However, any overdesign would introduce performance penalties, and the payload or the range might be significantly reduced. Consequently, simultaneous control demands, which relate directly to bleed-air demands, must be precisely specified; however, such control requirements have not been adequately investigated and must be studied further before firm requirements can be established.

To obtain information on the nature of simultaneous control usage, the Langley Research Center used an inflight simulator (Fig. 4-17) to measure the amount of simultaneous control a pilot would use in performing various operational tasks in a vehicle



Fig. 4-17. NASA CH-46 variable stability helicopter.

with control response characteristics similar to those of a jet VTOL aircraft.

The simulation technique which was used eliminated trim and disturbance effects, and the simultaneous control usage for maneuvering was analyzed in terms of relative bleed-air demands. The results indicated that whenever high total usage did occur, it lasted only a few tenths of a second. No simultaneous complete control demands occurred during any of the maneuvers, and the largest simultaneous control demands were significantly less than the sum of the individual maximum control demands.

Another possible means of reducing the maneuvering control power requirement for a hovering vehicle, is to provide a capability for wings-level translation and thus eliminate the necessity of rolling the airplane to achieve a sideward thrust component. The variable-stability X-14A (Fig. 4-18) was chosen for a preliminary flight evaluation of such a system, and a multi-axis motion simulator was used for a preliminary investigation and for the final selection of the control system.

A side-force vane, immersed in the jet exhaust of the X-14A just below the diverters, deflected the jet sideways through a small angle and was controlled by a device on the pilot's control stick, which could provide either proportional or on-off control. The



Fig. 4-18. The X-14A.

side-force vane with proportional control was evaluated in flight for the performance of lateral offset maneuvers of 1 to 2 wing-spans translation distance. For this task, the use of the vane for translation was preferred over roll when only a low value of roll-control power was available; with a higher control power available in roll the two methods were equally acceptable. For the more complex task of maneuvering around a prescribed course, the direct side-force controller was not preferred because it introduced another pilot input into the system that had to be coordinated (in flat turns, etc.) and could be easily misapplied.

Previous studies indicated that such jet VTOL aircraft experience aerodynamic interference effects during hovering and in the transition-speed regime between hovering and conventional flight. In order to determine the effects of jet location systematically, an exploratory investigation of jet locations several wing-chord lengths behind an unswept wing was made in the Langley 300-mph 7- by 10-foot tunnel. Various vertical locations of the jets were also investigated. The main purpose of the investigation was to study a rather large number of jet-exhaust locations to determine in a generalized manner the favorable and/or unfavorable effects of the various jet locations on the forces and moments on the wing and to indicate trends rather than provide performance data. The unswept, untapered wing had an aspect ratio of 6 and was equipped with a 30-percent-chord slotted flap. The two jets,

one on either side of the simple fuselage, were located span-wise at the 25-percent semispan station and were mounted independently of the wing so that only the aerodynamic forces and interference effects were measured on the wing.

It was found that locating the jet exhaust ahead of the wing was detrimental to wing lift, with the detrimental lift interference reaching a minimum at approximately 0.8 chord below the wing. Locations of the jet exhaust above this plane increased the detrimental interference effect on the lift which rose rapidly with upward vertical movement of the jets above the wing chord line. Minimum interference of the jets on wing lift occurred for jet locations below the wing near the wing midchord. Aft of the wing midchord, favorable lift interference was obtained. The favorable lift interference was more pronounced near the lower surface of the wing, especially near the wing flap. At jet locations aft of the wing, the favorable lift interference was relatively unaffected by vertical movement of the jets. The effect of the jet exhaust was less pronounced on the drag and pitching moment of the wing than on the lift. Pressure-distribution data for the wing and flaps indicated that the interference effects of the jet exhaust on the aerodynamic characteristics of the model resulted largely from a change in the effective angle of attack of the wing.

Reducing the jet deflection from  $90^\circ$  to  $60^\circ$  reduced the magnitude of the detrimental and of the favorable interference on the wing lift. Retraction of the wing flaps from  $40^\circ$  to  $0^\circ$  resulted in an increase in the detrimental lift interference, and the results indicated that the jet must be located near the trailing edge of the wing before favorable lift interference can be obtained for zero flap deflection.

*STOL Aircraft.*—Several methods of increasing lift to improve the low-speed takeoff and landing performance of subsonic jet transport aircraft have been investigated. (Fig. 4-19) An external jet-augmented flap with direct-lift control, which may meet these requirements, was recently tested in the Ames 40-by 80-foot tunnel, using a wind-tunnel model representative of current turbo-fan-powered transports.

The trailing-edge flap system—a main flap with full-span, blowing boundary-layer control, and an extended chord auxiliary flap with external flow jet augmentation—was found to be an effective high-lift device at low-thrust-to-weight ratios (0.05 to 0.10). The flap system also provided a method of direct-lift control by deflecting the auxiliary flap.

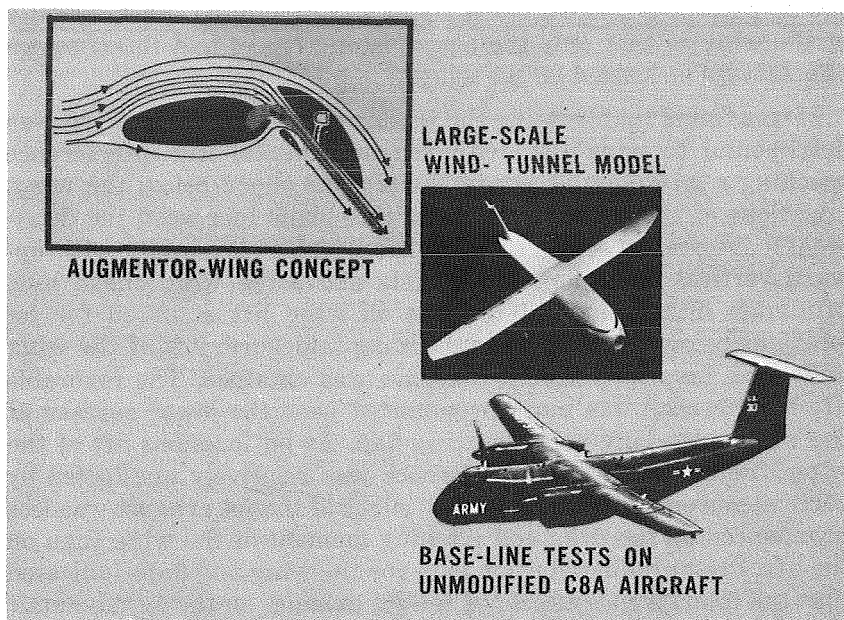


Fig. 4-19. Jet STOL research.

At each main flap deflection tested, this flap system increased lift coefficient and maximum trimmed lift coefficient significantly compared to the system without external flow jet augmentation. A maximum trimmed lift coefficient of 2.54 was attained with the main flap deflected  $30^\circ$ . Performance computations indicated that by deflecting the auxiliary flap with the main flap deflected  $30^\circ$ , this flap system could provide 0.2 g incremental normal acceleration at an approach speed of 117 knots or a  $4^\circ$  change in flight-path angle at approach speeds from 133 to 108 knots.

#### Supersonic Transport

Investigations were conducted in various NASA wind tunnels to determine the low-speed stability and control characteristics of a highly swept, arrow-wing-body supersonic commercial air transport concept. The model was tested in its basic configuration and with modifications. The static force tests showed that the basic configuration had longitudinal instability in the form of a pitch-up at an angle of attack of about  $20^\circ$ , and a deep stall problem, which could become a "locked-in" trimmed condition at a high angle of attack, in this case, at  $40^\circ$ . The basic design was modified by pro-

viding bluntness to part of the wing leading-edge and wing leading-edge devices, such as droop leading edges along the inboard semi-span and Krueger type leading edge extensions at the wing tip. In this modified configuration, the model had satisfactory longitudinal flight characteristics at low to moderate angles of attack. Pitch-up within the operating envelope and deep stall were eliminated.

#### Military Aircraft

At the request of the Navy, NASA conducted wind tunnel tests to determine the performance of F-14 aircraft, evaluated the results, and was preparing estimates of the most likely maneuvering performance, weight, range, aerodynamic, and propulsion characteristics of this aircraft to present to the Navy.

At the request of the USAF, NASA also started wind tunnel tests of three contractor proposed F-15 aircraft and will provide the results, corrected to full scale flight conditions, to the USAF. In addition, NASA will also make available to the USAF about 30 advisors to assist in the evaluation and provide technical assistance. (Fig. 4-20).

#### XB-70 Flight Research Program

The XB-70 flight program ended on February 4, 1969, with delivery of the XB-70 Number 1 to the Air Force Museum at Wright-Patterson Air Force Base, Ohio. With this final flight of the aircraft, on which research data were obtained as planned, the two aircraft completed a total of 129 flights and a total flight time of 252 hours and 38 minutes.

NASA research provided data for the design and operation of future large supersonic-cruise aircraft. In addition to sonic boom work, it was directed primarily to the following areas.

*Flight Dynamics.*—This portion of the program provided information on the aerodynamic characteristics and flight behavior of a large flexible supersonic-cruise airplane. To evaluate the accuracy of predesign predictions and the influence of aeroelasticity, a fairly complete set of stability and control derivatives was measured throughout the flight corridor of the airplane (Mach number versus altitude); the influence of dynamic pressure on derivatives was determined; and an attempt was made to resolve the differences between predictions and flight results. In general, reasonable agreement was achieved except for several notable flight conditions. A large discrepancy between actual flight-measured and predicted elevon trim positions was traced to small variations in the wind-tunnel model design. The aeroelastic predictions, however,

generally were confirmed by the flight-measured data. A large discrepancy between predicted and flight-measured effects of aileron yaw remains unexplained, although elasticity may be a factor in it. Additional calculations and wind tunnel tests are planned.

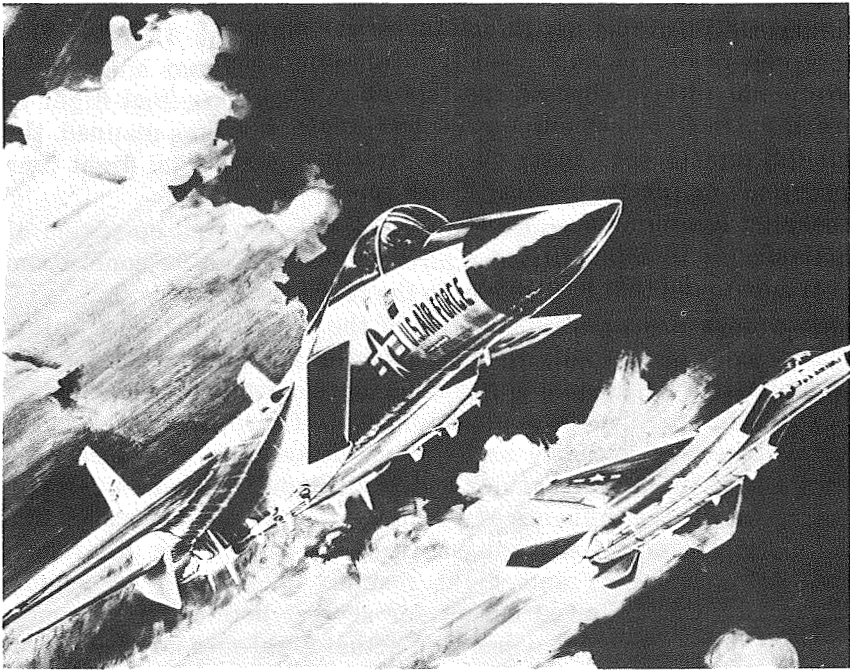
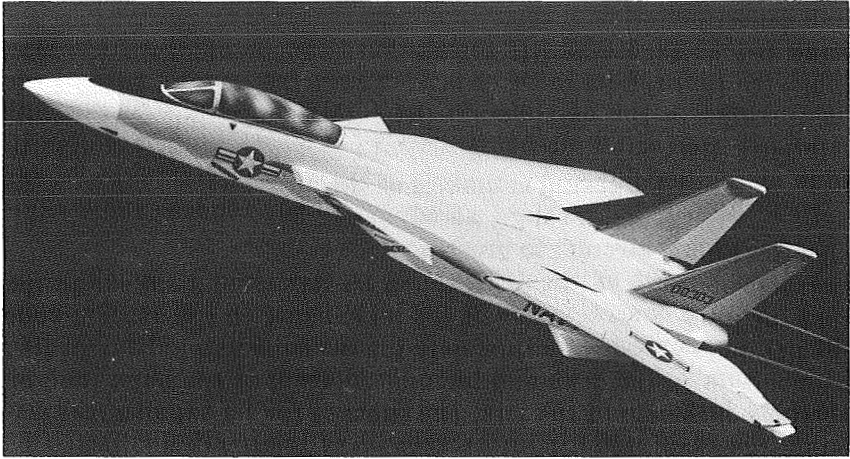


Fig. 4-20. F-14 (top) and F-15 aircraft.

Results of the XB-70 handling qualities program indicated that existing longitudinal frequency and damping criteria for transport aircraft may be too conservative at low levels of frequency and damping.

The XB-70 also provided information for analysis of specific piloting problems. The inability of the pilot to manually control altitude precisely at Mach 3 (altitude oscillations in excess of  $\pm 1000$  feet) is believed to have been strongly influenced by phugoid dynamics. Pilot induced aircraft oscillations during lateral control movements were found to be caused by the interaction of negative dihedral and adverse yaw. These results correlated well with existing criteria.

Control usage and airplane response parameters are being documented in the form of histograms, which provide an indication of the maximum rates, accelerations, and control deflections used throughout the flight program, and the probability of occurrence of various values. In addition, baseline data were derived for correlating ground-based and airborne simulators.

The XB-70 was tested at low speeds, particularly during approach and landing operation, to evaluate the behavior of a large supersonic-cruise aircraft in the terminal area. The results indicate that  $3^\circ$  glide slopes are unacceptable for this class of aircraft at approach speeds of 200 knots or more. Experience with the XB-70 during landings indicated that judging height in the flare was a problem for the pilot due to the high approach speeds and the long distance between the pilot's position and the location of the main landing gear.

*Air-Induction and Propulsion Systems.*—The XB-70 steady-state inlet system characteristics were investigated in the higher speed portions of the flight envelope. Inlet characteristics were measured in terms of compressor face flow recovery and distortion. Problems associated with operating as near to peak inlet efficiency as possible without creating an unstable shock transient and unstating the inlet were determined during several planned inlet unstarts at Mach numbers above 2. These data enabled comparisons to be made between flight tests and similar tests in ground-based facilities. The flight data were also used to develop a digital dynamic simulation technique. The simulation was used to evaluate the unstart transients, atmospheric turbulence effects, and the effect of an external shock wave caused by a passing aircraft (F-104).

A series of turbulence tests were performed with the XB-70 inlet at Mach numbers above 2. The data allowed comparison with

previously obtained ground facility data and also with F-111 flight data measured near compressor surge conditions. A number of supplemental tests were carried out at lower speed to measure the off-design operational aspects of high-speed inlets.

*Airplane Performance.*—During the flight program, a new method of determining in-flight thrust was used which proved to be accurate to within  $\pm 3$  percent. Additional wind tunnel tests will be made to obtain performance characteristics over the Mach number range for comparison with flight data.

A new technique for analyzing ground effect was developed specifically for correlation with the XB-70 flight results, and good agreement between flight-measured and wind-tunnel results was obtained. Also, the effects of atmospheric and aircraft variables on takeoff performance were evaluated.

*Local Flow and Boundary Layer Characteristics.*—An extensive survey of local base pressure was made. Comparison of the XB-70 base drag with predicted levels revealed significant differences in specific regions of the Mach envelope. Another local phenomenon which results in proportionately different drag at full-scale than at the model scale is the flow over an abrupt discontinuity, such as an aft-facing step. Such a step was placed on the XB-70 wing and effects on the local flow were determined. In addition, local friction was measured using three boundary-layer complexes installed on the wing and fuselage.

*Aerodynamic Loads.*—Flight load measurements were acquired at Mach numbers from 0.40 to 3.0, and some aeroelastic information was obtained. The findings indicated close agreement between predictions and flight measurements, except in the transonic regions where minor deviations were observed. A source of airplane buffet during subsonic flight was traced to the canard. The information obtained during the flight tests indicates that particular attention should be given to prediction methods in the transonic region and to airfoil shapes and configurations if optimum hypersonic-supersonic characteristics are desired.

*Engine and Aerodynamic Noise.*—Measured and predicted engine noise levels at the higher power settings were in reasonable agreement for ground operation, but refinement of the prediction method is required.

Inconsistencies were found between flight and wind-tunnel boundary-level noise pressure fluctuations data. The inconsistencies were produced by the different transducers used in the various studies and will require additional wind-tunnel and laboratory transducer evaluation. When the reasons for the inconsistencies

are determined the results should be useful to airplane designers, enabling them to optimize the design of aircraft panels for fatigue resistance and acoustic insulation related to passenger comfort.

*Dynamic Response.*—Data were obtained during normal operation of the XB-70 airplanes relative to atmospheric conditions and vehicle response to encounters with high-altitude turbulence and relative to the landing loads and other landing-contact conditions. In addition, studies were made of aerostructural damping characteristics and of a system for improving the damping in order to alleviate effects of gust disturbances. Landing contact conditions were compared for XB-70 and modern turbo-jet transports, and statistical analysis of landing contact conditions for approximately 70 landings was made.

Comparison of atmospheric conditions above 40,000 feet with weather data provided additional information on the effects of wind speed, wind shear, and temperature on clear-air turbulence between 40,000 and 74,000 feet. Measurements of the dynamic response of the aircraft to clear-air turbulence were obtained during 96 supersonic flights over the western United States. The data provided information on the amount of turbulence encountered and indicated that turbulence exists in the altitude region above 40,000 feet over a greater percentage of the distance flown than was reported in previous studies. The XB-70 data showed that the structural modes contribute an appreciable amount to the overall acceleration response to atmospheric turbulence. In addition, atmospheric turbulence encountered simultaneously with the response of the airplane to a known gust input was measured. Data from approximately 22 flights were collected.

An aerodynamic shaker system was installed on the airplane to determine the various structural modes of the airplane in flight and to obtain the damping associated with each. Data were obtained over Mach numbers ranging from 0.5 to 2.40, and at altitudes from 10,000 to 62,000 feet for various weight conditions. The flight data are being compared with data from an analog simulator, which included all of the aircraft hydraulic and control systems, to define the behavior and effectiveness of the systems for controlling the first four structural modes, both subsonic and supersonic. In general the system showed more effectiveness in suppressing vehicle response at supersonic than at subsonic speeds. Limited results of the system operating in turbulence showed that the system was effective in reducing the airplane response for the one flight condition evaluated (Mach No. 1.9 at 39,000 feet).

*Environmental Effects.*—Thermo, acoustical and acceleration data inside the cockpit and mid-fuselage areas of the airplane were measured. Comparisons were made between the test data and design predictions, and between the XB-70 crew compartment environment and that of other military and civil aircraft.

*Piloting Factors.*—Information pertaining to the operational problems and experiences of the pilots in ground-handling and airborne operations were measured. Crew training requirements, pilot workload, and work-sharing problems, takeoff/landing visibility problems, and ground-handling experience and climb/descent procedures were measured and documented.

#### X-15 Research Aircraft Program

Manned space flight, not aeronautics, was the immediate benefactor of the recently concluded X-15 research program (*20th Semiannual Report*, p. 118). A review of the contributions of the program and their actual use makes it abundantly clear that the space-oriented results have been of greater value and importance than the hypersonic aeronautics contributions. This is the reverse of what was expected in the beginning.

The X-15 program was the first major investment of the United States in manned aerospace flight technology. Its broad objective was to take a long step forward in developing the new technologies needed for hypersonic aircraft. It was not proposed as a prototype of any particular system concept but as a general tool for manned hypersonic (Mach 5) flight research, capable of penetrating new regimes briefly and safely without the burdens or delays imposed by other requirements.

The last X-15 flight, the 199th in a program that began on June 8, 1959, was made on October 24, 1968. Another flight—the 200th—was scheduled eleven times after this but each time the proposed flight was cancelled, five times because of inclement weather, six for technical reasons.

The X-15-1 was donated to the Smithsonian Institution, with ceremonies transferring ownership of the airplane from the Air Force to the Smithsonian on June 10, 1969. The X-15-2 will be displayed at the Air Force Museum, Wright-Patterson Air Force Base, Ohio. The X-15-3 was destroyed in an accident on November 15, 1967. Table 4-1 shows program accomplishments, and the following section summarizes information obtained in several key areas during the course of the flight program.

	X-15-1	X-15-2	X-15-3	Maximum, Total, etc.
First flight (captive) ----	3-10-59	7-24-59	--	--
First flight (glide) -----	6- 8-59	--	--	--
First powered flight -----	1-23-60	9-17-59	12-20-61	--
First research flight -----	3-25-60	3- 7-61	12-20-61	--
Maximum altitude -----	8-21-68 (267,500 feet)	8- 3-66 (249,00 feet)	8-22-63 (354,200 feet)	354,200 ft.
Maximum velocity -----	6-27-62 (4104 mph; M5.92 12-5-63 (4018 mph; M6.06	10-3-67 (4520 mph; M6.70	10-4-67 (3897 mph; M5.53 12-20-62 (3793 mph; M5.73	M6.70 (4520 mph; M6.70
Number of flight attempts	142	97	97	336
Total number of flights ---	81	53	65	199
Last flight -----	10-24-68	10- 3-67	11-15-67	10-24-68

*Piloting.*—A major goal of the program, and one which has been most successfully achieved, was to explore the capabilities and limitations of the human pilot in an aerospace vehicle. The space trajectory and reentry maneuvers to be performed by the X-15 pilot were guaranteed to provide a convincing test of the role of the pilot, a serious question in the early 1950's.

Because there were no two-seated versions of the X-15 in which pilots could be taught to fly, the pilots were required to learn on ground-based simulators. The 12 pilots were trained this way with outstanding success, and this experience paved the way for similar all-out use of simulators in the space program.

The X-15 program shows clearly that, given precise displays, the pilot can fly rocket-powered vehicles into space with great accuracy. Attitude control in space, a serious unknown in 1954, was shown to be a skill readily acquired by pilots.

The steep reentries of the X-15 with flight path angles up to minus 38 degrees, speeds approaching Mach 6, and steep angles of attack presented a more difficult piloting problem than the shallow entries characteristic of manned orbital flight. With the X-15's systems operative, the pilots could perform the reentry maneuver readily.

With a few exceptions, weightlessness and the high heart rates associated with this type of flying produced no difficulties. Both of these factors were large unknowns before the X-15 program.

An analysis of the first 44 flights showed that 13 of them would have failed in the absence of a human pilot together with the various redundant systems in the airplane. Against these figures in favor of the pilot, there were only a few examples where the pilot's error degraded the mission performance, and only one catastrophic accident out of the 199 flights.

A broad positive finding of the program is clear: the capability of the human pilot for sensing, judging, coping with the unexpected, and employing a fantastic variety of acquired skills remains essentially undiminished in all of the key problem areas of aerospace flight.

*Hypersonic Aerodynamics.*—Virtually all of the pressures and forces measured in flight were found to be in excellent agreement with the low-temperature wind-tunnel predictions. With this broad validation from the flight tests, the conventional low-temperature hypersonic wind tunnel has become the accepted tool for future configuration development.

*Turbulent Heat Transfer.*—Because of major limitations of theory and an almost complete lack of reliable hypersonic wind-tunnel data, there was initially great doubt about the predicted turbulent heating rates for vehicles of this speed range. The measured flight data showed a marked departure from the available predictions, averaging about 35 percent lower, and this significant difference stimulated the development of new prediction methods and new ground-based investigations. The high-lighting of important problem areas and the stimulating of new research exemplifies one of the greatest values of an exploratory research airplane.

*Structures.*—The thick-skin heat-sink type of metal structure adopted in the design of the X-15 made possible a wide range of flight missions, including steep reentry. No unexpected incidents occurred in flight for the primary structure. However, many unanticipated local heating problems were found in the secondary structures, and they were solved. These failures point out the fact that what are considered minor design details of a slower craft must be dealt with as prime design problems in hypersonic vehicles. This knowledge was put to use in the precise design of a host of important details on the manned space vehicles.

*Operational Subsystems.*—It was necessary to use many newly conceived, partially developed subsystems on the X-15. In spite of extensive environmental testing, new problems were encountered after the start of flight operations. In this area, the X-15 brought to light many "real" problems that could not have been foreseen by any other means than involvement with an actual flight vehicle.

Many specific new requirements for aerospace developmental testing were identified and were of great value in subsystems development for the space program.

*Follow-On Experiments.*—Early in the program, it became apparent that the X-15 could perform a valuable function, not foreseen in the original planning, as a reusable carrier for a wide variety of scientific experiments, most of them dealing with space programs. More than one experiment was carried on many flights, and the X-15 system, unlike space rocket testing, permitted full recovery of the equipment, recalibration, and repeated runs where needed. In nearly all cases, use of the X-15 was the least costly and quickest means of achieving the desired results.

*Other Contributions.*—Over 700 different technical documents were produced; 200 of the documents reported general research that would have not been undertaken had it not been for the stimulus of the X-15.

Probably one of the most important contributions, and an intangible one, is the acquisition of new "know how" by many teams in government and industry. Working together, they had to face up to unprecedented problems, develop solutions, and make this first manned aerospace project work. They remain an important national asset in the space program.

The result of the focusing and stimulating effects of the X-15 program was to generate aerospace vehicle technology at a highly accelerated rate and to provide a massive backlog of aerospace technology for the space program.

## BIOTECHNOLOGY AND HUMAN RESEARCH

### Human Research

*Community Reactions to Airport Noise.*—As part of a program recommended by the Office of Science and Technology, Executive Office of the President, an extensive acoustical and sociometric survey was being made around major airports to determine the various psychoacoustic responses to noise. On the basis of this research, quantitative noise evaluation techniques and standards can be developed for use by the FAA, airport operators, and aircraft/engine manufacturers. In Phase I of the study, 5400 interviews were conducted in three regions around the airports (0-3 miles, 3-6 miles, and 6-12 miles) in Chicago, Dallas, Denver, and Los Angeles. The data are being analyzed and will be used by the FAA in aircraft certification. Phase II includes 4000 interviews

around the jet airports of Miami, New York, and Boston. Miami was completed and New York is underway. The study has shown that many factors other than level of noise exposure are important in explaining the reactions of people to aircraft noise. Two such factors are day and night values of PNdB (perceived noise in decibels) and the number of flights. The scientific data now becoming available will be useful in assaying the contribution of social factors in predicting the effects of noise disturbance and will also be useful in noise abatement programs.

#### **Sonic Boom: Public Reaction Studies**

This study, which is part of the effort to assess noise pollution scientifically in order to provide a basis for rational public policy decisions, deals primarily with public reactions to modest sonic boom over-pressure levels generated by supersonic flights over Dallas/Fort Worth, Denver, Atlanta, and Chicago in late 1967. The study identified major social, economic, and psychological factors found to be associated with one or another type of public reaction in these metropolitan areas. About 2,670 pre-test interviews were obtained before the first overflights, and a post-test sample of about 1,000 interviews was obtained. The final report was in the review stage.

#### **Bone Mineral Loss**

The demineralization of bone, such as that discovered on the Gemini and Apollo flights, was studied to determine whether the loss of calcium is inexorable or can be prevented or reversed by exercise. Volunteers at the U.S. Public Health Service Hospital in San Francisco have spent over 5 months in bed simulating the weightlessness of space flight. (Fig. 4-21) During the first three months they engaged in 80 minutes of moderately vigorous physical exercise each day. The hope was that the loading of bones during exercise would substitute for the postural loading normally found in the 1 G environment of the earth's surface. Assessment of their calcium balance after the three months revealed a disappointingly slight beneficial effect and indicated that a prohibitively high exercise load would be necessary to approach complete reversal of loss. Although the result was discouraging, it did direct attention to dietary measures as a means of controlling calcium loss. Dietary supplements, such as phosphorus, may be beneficial; they may also eliminate the inordinate amount of crew time needed for the exercise program.

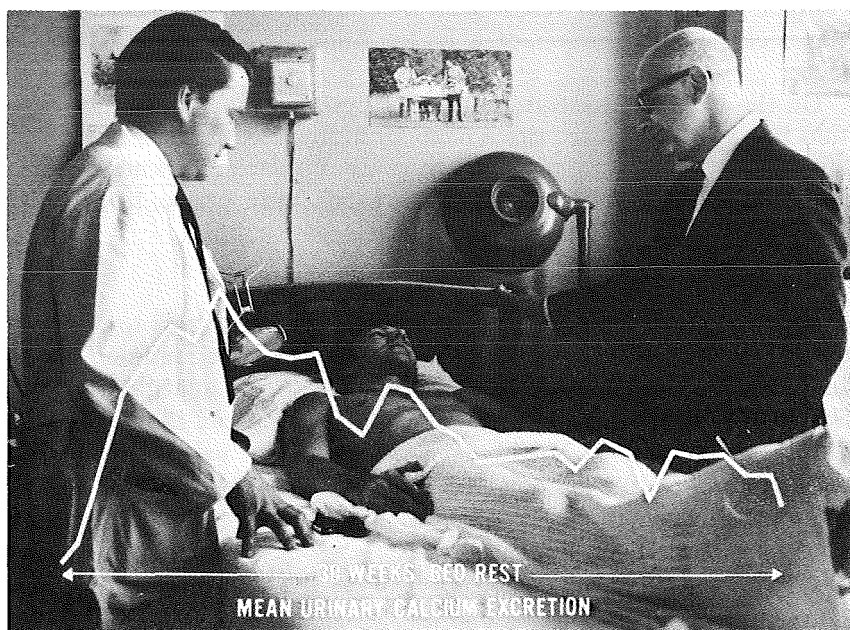


Fig. 4-21. Effects of weightlessness on bone.

### Apollo Sickness

On two of the first three Apollo flights, the astronauts for the first time developed "queasiness" if not outright nausea and vomiting. The feeling was associated with movement around the cabin during the early phases of the flights.

Earlier, NASA's Human Research Program, recognizing the possibility of such a reaction, supported an exhaustive investigation at the Naval Aerospace Medical Institute of the efficacy of various combinations of antimotion sickness drugs. The study revealed that the *combination* of two widely used remedies, scopolamine and dexadrine, was significantly superior to other more glamorous and popular combinations. The tests for motion or Coriolis sickness were conducted in a Slow Rotating Room, a room which could rotate smoothly at up to 10 rpm, and furnished and stocked to permit subjects to live in it for over a month at a time.

Another application of the Slow Rotating Room was the development of a controlled series of head movements, so graduated that frank Coriolis sickness would not occur, but which stimulated the vestibular apparatus of the subjects to a degree which effected adaptation to the rotating environment much sooner than would

random activity. The result was that this particular form of motion sickness was no longer a factor limiting the activity of subjects.

On the basis of these studies, it was possible for a recommendation to be made, before the Apollo 10 flight, for the optimum combination of drugs to prevent or combat motion sickness and a program of head movements for the early flight phase, to expedite adaptation to weightlessness.

#### Man-Systems Integration

In a study to determine the ability of a selected crew to perform meaningful tasks in a hostile environment, four Department of the Interior marine scientists completed 60 days of isolation and confinement in a habitat 50 feet below the surface of the Caribbean Sea. (Fig. 4-22) A NASA-developed two-gas sensor controlled the atmosphere in the habitat. NASA was interested in the behavior of the crew under stress and in habitability of the vehicle. Early findings indicated that small crews can perform effectively under conditions of isolation and stress by working together on real mission activities.

Ames Research Center developed a catalog of tools that can be used in space. The data include the weight, dimension, work capabilities, procedures for use, operational constraints, and manufac-

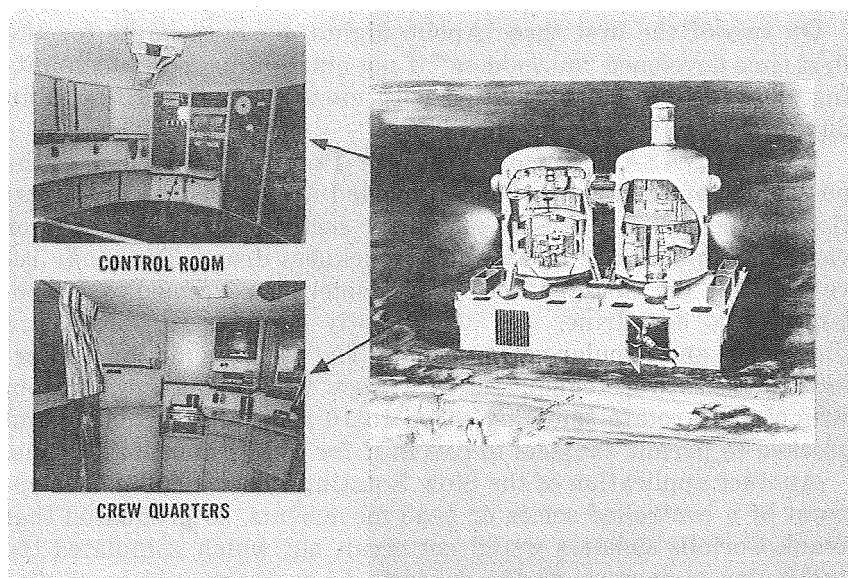


Fig. 4-22. TEKTITE habitat.

turer identification for each tool, thus consolidating all the information in a single document for use by engineers and mission planners.

A navigational sextant used in Apollo 9 as a back-up instrument was checked at the Ames Research Center for accuracy in a glare field. The laboratory-derived data are being used to develop a correction table (for future use in space) to eliminate errors in position fixing attributable to the effects of glare.

#### Life Support and Astronaut Protective Systems

*Oxygen Generating System.*—In the *20th Semiannual Report*, an on-board oxygen generation system for application to tactical military aircraft was discussed. Progress during this period was made in the following areas. Laboratory breadboard system tests were completed, following some 6,000 hours of continuous runs for the water electrolysis and carbon dioxide concentration cells. A flight breadboard system with accessories and recording equipment was fabricated and subjected to preflight tests. Flight tests, to begin in July, 1969, will provide data and performance characteristics to be applied to the next generation unit.

*Atmospheric Sensing System.*—Several units of a NASA developed mass spectrometer for analysis of the major atmospheric constituents (nitrogen, oxygen, water vapor, carbon dioxide) underwent various tests of their analytical capability. One unit was used in a series of chamber tests on carbon dioxide levels at the Air Force School of Aerospace Medicine. Two were being evaluated at Marshall Space Flight Center, one as a rapid rate, metabolic sensor, another as an atmospheric sensor and control device in the orbital workshop program. A similar unit was used on the TEKTITE Project (p. 122).

*Water Reclamation.*—The NASA-Federal Office of Saline Water (OSW) joint development effort on the use of porous glass tubes as membranes in a reverse osmosis (RO) process continued to advance (Fig. 4-23). RO, one of several processes under investigation by OSW and NASA, is applicable to a wide range of water purifying problems and has a number of operational advantages. The glass (inorganic) membranes can withstand the high temperatures of heat sterilization, do not support the growth of bacteria which cause clogging and deterioration, and are chemically inert and resistant to corrosion. The RO units can purify sea water, brackish ground water, and human waste water, and can also be used in processing of food such as juices and in dialysis of urea and salt solutions required by artificial kidney devices.

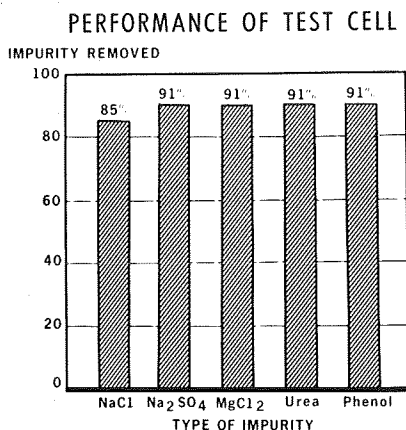
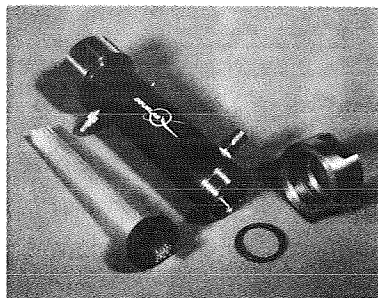


Fig. 4-23. Reverse osmosis test cell.

Recent tests indicated that glass membranes can reject more than 97 percent of the total dissolved solids from feed water, i.e., salts, urea, phenol, and other organic materials, nitrates, borates and sulfates. The optimum pore size for maximum rejection was theoretically determined to be 40 angstroms. However, it was found that a very slight increase in pore diameters results in an almost complete loss of solid waste rejection capability. Ames Research Center is carrying on a more thorough evaluation of the technique, concentrating on the dissolution of the pores from high salt concentrates.

*Constant Volume Hybrid Space Suits.*—Space suit mobility limitations, one of several factors causing difficulty on EVA missions, were being overcome with constant volume joints developed in NASA hard space suit systems. Two hybrid space suit systems manufactured by two contractors were delivered to MSC in February and March. (Fig. 4-24) In the two systems, total weight was reduced from 55 to 40 pounds, and torques were reduced from 10-20 foot pounds to 0.5-2.5 foot pounds by applying the constant volume joint principles. Both suits incorporate the NASA "stove-pipe" joint principle; one utilizes the "nesting" bellows constant volume joint, the other the rolling convolute constant volume joint developed in the RX series hard space suit.

Quick donning capability in the hybrid space suits was achieved through use of single axis body seal closures, rather than pressure

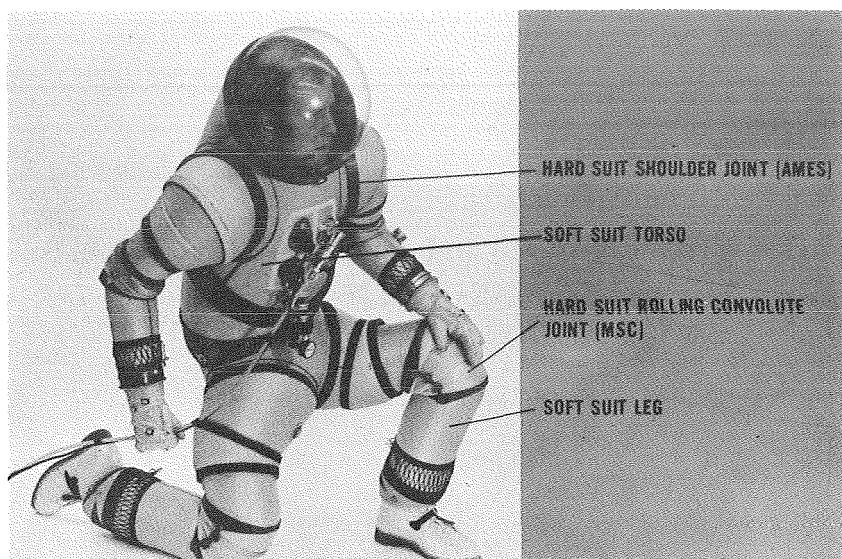


Fig. 4-24. Hybrid space suit.

sealing zippers. The new closures have the additional advantage of low leakage.

#### Weightlessness Experiments Program

A number of investigations were being conducted on the effects of extended weightlessness on man, corrective measures, and suitable life support and protective systems.

Progress was made on the orbiting frog otolith flight experiment—basic research on the adaptation of the gravity dependent sensor in the inner ear (the otolith) to weightlessness. (Fig. 4-25) The experiment will monitor the nerve signal from an otolith sensor and record its reaction to the weightless exposure. The project (originally planned for Apollo) was rescheduled to a Scout vehicle and launch time was put ahead to 1970. Although the principal investigator, a visiting Research Fellow from Italy, completed his tour with NASA during this time, he has been retained as the principal investigator under an agreement between NASA and Italy.

NASA evaluated and accepted the proposed design and authorized the construction and flight qualification of the hardware. Procurement of long lead items was initiated and fabrication started. The experiment preparation support equipment was installed,

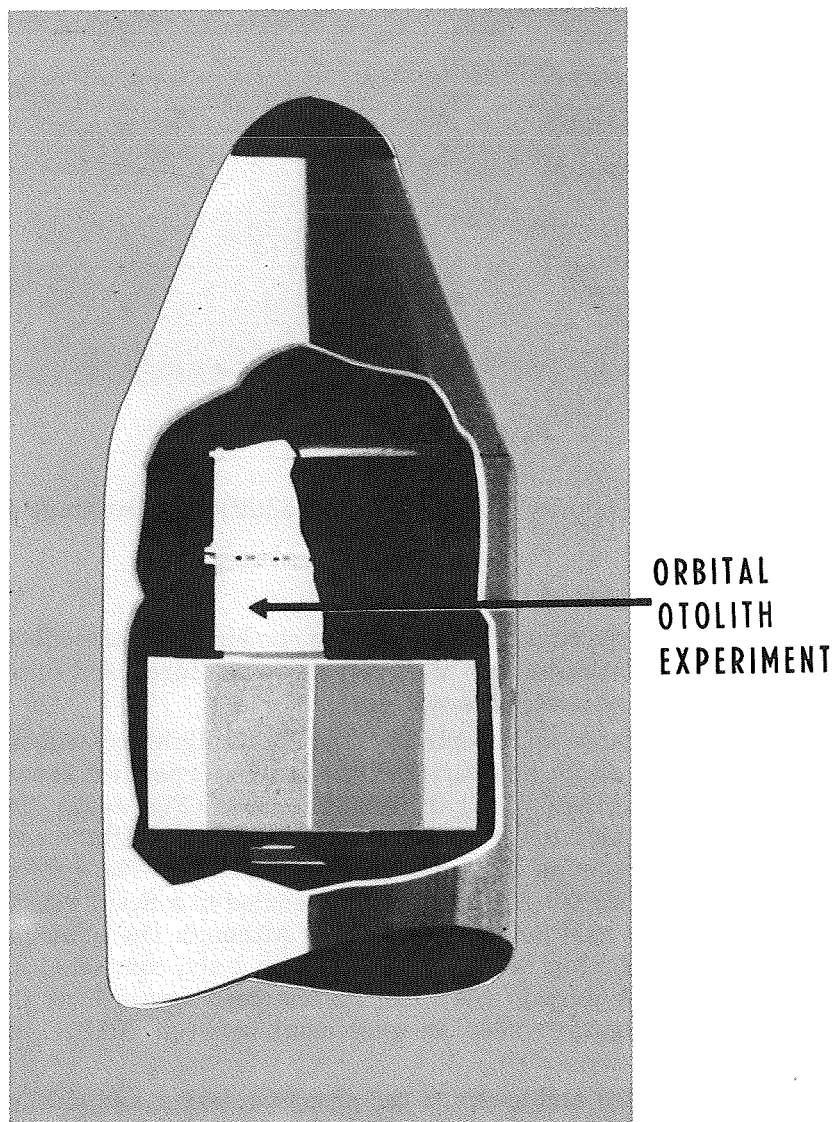


Fig. 4-25. Orbital otolith experiment inside flight package.

preliminary run through begun, and the experiment packages thoroughly tested for flight readiness.

## ADVANCED PROPULSION SYSTEMS

Work in this area is concerned with motors using solid propellants and systems using liquid propellants. Hybrid systems and tripropellant combinations are also being studied. Thrust levels range from millipounds, for attitude stabilization of small spacecraft to millions of pounds for launch vehicles.

### Solid Propulsion Systems

The first year of work was completed on a tribrid rocket propulsion system, which is an extension of hybrid technology introducing liquid hydrogen as a third component. The theoretical vacuum specific impulse for this tribrid lithium/fluorine/hydrogen system is 505 lb seconds/lb. Problems of fuel grain formulation and fabrication and combustion efficiency were studied. In small scale tests (6 inch diameter), 475 lb-sec/lb were delivered from a formulation whose theoretical performance was 498 lb-sec/lb. Future work will emphasize regression rate and extinguishment characteristics of the fuel grain.

Progress continued in metal combustion research which seeks to increase understanding and control of metal combustion in solid rocket propellants. In this application, metals are a useful propellant ingredient only if they react completely and do not impair other combustion characteristics such as stability and burning rate. The details of the metal combustion process in propellant flames are extremely complex, but have been substantially clarified by studies of behavior of single and multiple particles in simpler laboratory experiments during this program. The experiments revealed the nature and behavior of protective oxide coatings on unignited particles, the breakdown of coatings to permit sintering and agglomeration, and the ignition and combustion of particles. The observations substantially clarified behavior observed in propellant combustion and provide a means for rational selection and modification of ingredients to change combustion behavior.

Intensive research efforts were applied to studying fracture in polymeric materials (rubber, propellants). Current work used Electron Paramagnetic Resonance (EPR) techniques to study mechanical fracture in these plastic materials. EPR provides a means of monitoring the presence of unpaired electrons which are associated with the free radicals resulting from the breaking of the

covalent bonds in polymers. This work showed that EPR techniques can be used to study bond rupture of polymers during mechanical stressing as well as the combined effects of mechanical stress and ozone attack.

These problems, which are economically important to solid propulsion technology and to the plastics and rubber industry as a whole, are to be subjected to further extensive study.

A research program to develop a microwave nondestructive testing technique was successfully completed. The method, which can detect voids and laminar flaws within solid propellant grains too large for inspection by conventional techniques, is being successfully applied to inspection of commercial aircraft tires and parts of two DOD missiles (Fig. 4-26). Effort is continuing to adapt this technique to very large solid rocket motors.

A contract was let for the design, construction, and testing (late in 1969) of a high energy hybrid motor. This motor, combining features of solid propellant and liquid propulsion systems will develop about 15,000 pounds of thrust and should be capable of any number of stops and restarts. Objectives include demonstration of

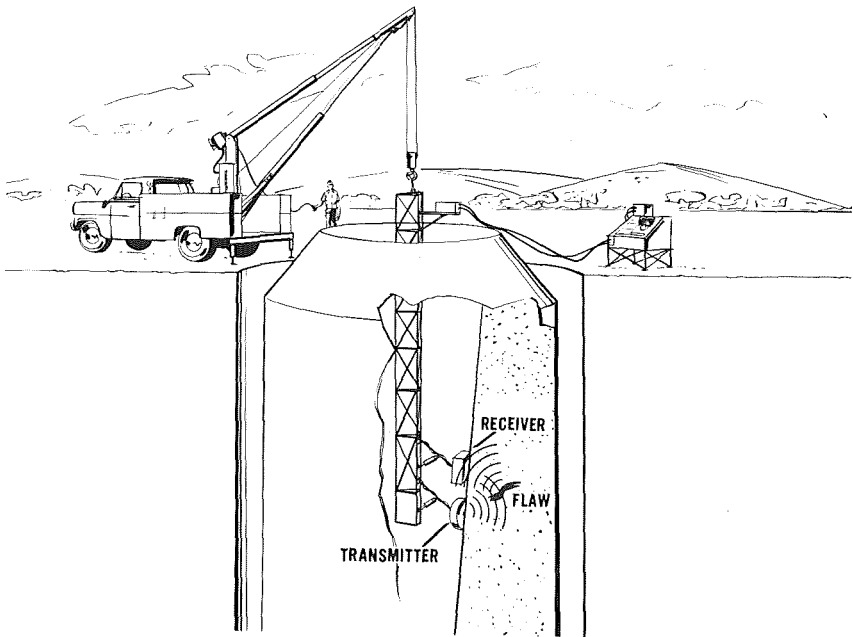


Fig. 4-26. Concept for microwave inspection of large solid motor grain.

manufacturing feasibility, development of 30 percent more energy than a solid propellant motor, and thrust termination with a re-ignition. The first phase contract utilizes relatively heavy weight hardware that should prove all the basic premises of the system.

The program to demonstrate a high energy restartable solid motor weighing about 3,000 pounds was on schedule, with static firing of the first motor to take place in early 1970. Design of the fiberglass case, propellant charge, nozzle, and quench system was completed, and a scale model quench test was successfully carried out. This motor will develop 10 percent more energy than current solid spacecraft motors, and its restart capability will increase the high altitude orbit capability of current small launch vehicles. It is also being considered for use as a final propulsion stage in very high velocity missions such as those to the outer planets.

Advances in the large solid motor technology program continued. A solution was found for the propellant processing problem that caused expulsion of pieces of propellant during the last 260" motor firing in June 1967. (*17th Semiannual Report*, p. 99) In addition, a contract was let to develop better techniques for inspection of the finished propellant in a motor to assure detection of internal defects.

Several investigations of low cost ablative nozzle materials were underway. The sixth and final firing of the original 8" throat diameter ablative test nozzle was completed, and a new contract was let to apply the most promising materials in a 15" throat nozzle. Another 8" throat nozzle test program was initiated to study more radical approaches to ablative construction, particularly the use of moldable and troweled-on types of liners.

Under another contract, low cost chamber insulation materials and application processes were developed. The improved system, in which lower price materials are troweled in place and cured, performed well in firing tests. The cost of future insulation should be reduced more than 50 percent as a result of this work.

The use of Fiberglas as a large motor case material has always been limited by the fact that the nozzle-end opening would have to be very large with relation to the diameter of the motor case. Such a relationship adversely affects the efficiency of the helical winding patterns, and increases manufacturing problems. A 54" diameter Fiberglas vessel with a 38" diameter aft end opening (70%) was manufactured using an improved process. The vessel was pressure tested successfully and finally burst at 115 percent of its design pressure.

### Liquid Propulsion Systems

An analytical definition program to optimize the configuration of a 5,000 pound thrust FLOX-methane engine was completed concurrently with parallel programs to define the regenerative cooling capabilities of this propellant combination. The latter studies resulted in better understanding of heat transfer, which is applicable to the design of thrust chambers.

The high performance obtainable from the space storable Oxygen Difluoride-Diborane ( $\text{OF}_2/\text{B}_2\text{H}_6$ ) propellant combination was further confirmed in a series of carefully instrumented tests in an altitude-simulating facility. However, thrust chamber carbon erosion with diborane was found to be faster than expected, and diagnostic tests (such as operation with cool diborane-rich gas next to the wall) indicated that the problem results from chemical reaction of the boron compounds with the carbon. Several of the advanced cooling schemes, such as heat pipes, conduction cooling, and foam stabilization of the boundary layer, were studied as solutions. The feasibility of regenerative cooling using vaporized diborane as the coolant was also investigated. If the latter works, it may be possible to use diborane as a propellant at chamber pressures in the pump-fed range (500 psi). This would not only increase the performance, but also alleviate the expulsion bladder problem with these reactive propellants.

The ultra high energy tripropellant liquid system (lithium-fluorine-hydrogen) was tested in an altitude-simulating facility. It delivered about 505 seconds of specific impulse, as compared with 312 seconds for Apollo propellants, 450 seconds for oxygen-hydrogen, and 470 seconds for fluorine-hydrogen. The test was carried out at the 2,000 lb thrust level using a combustor cycle that greatly simplifies the engine design. In a conceptual study of this tripropellant system, an engine was designed that would weigh about 290 pounds for 15,000 pounds of thrust at a specific impulse of 519 seconds. In planned future work, this engine in space vehicles of various sizes will be compared with an advanced, but simpler, fluorine-hydrogen engine system.

Several projects in the field of improved turbomachinery were completed. Three different methods of improving cavitation performance were investigated, all involved use of a low speed inducer installed upstream of the main high speed pump. In each case, the dynamic relationship between pumps was defined analytically and then confirmed by component testing of subscale pumps. Additionally, an improved method of computing stresses and loads in rotating inducers was developed and will be confirmed experimentally.

## BASIC RESEARCH

## Fluid Physics

Significant progress was made in developing improved methods of predicting the sonic boom from aircraft maneuvering in a stratified atmosphere and in devising aerodynamic techniques for reducing sonic boom for practical aircraft designs. In a NASA-sponsored study, a technique was analytically developed for reducing sonic boom. The new method, which redistributes lift along the length of present supersonic transport configurations, produced maximum sonic boom overpressure of about one pound per square foot with no apparent performance penalty at cruise speed. This is a substantial reduction compared with the maximum boom overpressure of two to three pounds per square foot for present configurations. The theoretical models were being investigated experimentally in wind tunnel tests at Ames Research Center.

In addition, considerable research was done on the flow generating and propagating mechanisms of noise over compressor and turbine blade cascades, and on jet engine inlets and exhausts. Significant progress was made in research on the fluid dynamic mechanisms of noise generation from supersonic engine exhaust jets. A preliminary theory was developed for predicting noise from a supersonic jet exhaust; the theory was found to correlate well with experimental data. Experiments were underway to extend the theory for predicting the power spectra and the directivity for supersonic jets. The problem of noise reduction was also studied to gain an understanding of the basic flow mechanisms. Substantial noise reduction in supersonic jet exhausts was achieved by utilizing various aerodynamic techniques. A shroud-induced secondary flow mixed with the supersonic exhaust was found to act as a diffuser, converting the flow to subsonic velocities with a significant noise reduction and no penalty in thrust. Experimental studies were continuing to determine the fluid dynamic details of the flow and to identify the controlling physical parameters.

Investigations of flow conditions at the thin leading edge of lifting surfaces or engine intake ducts for hypersonic flight in a rarefied atmosphere indicated that slip flow occurs at the leading edge. Thus, the pressure distribution and heat transfer are substantially less—by as much as a factor of 10—than that predicted by the strong boundary layer-shock interaction theory for the denser atmosphere at lower altitudes. The result indicates that engine duct inlets made of materials such as tungsten could accommodate a broad range of hypersonic flight conditions. Studies were being

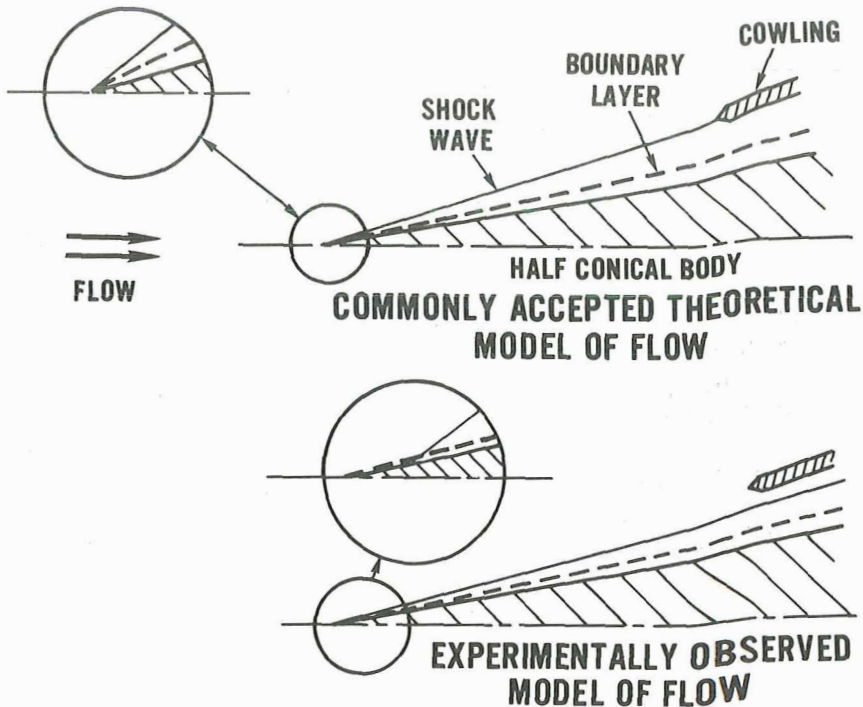


Fig. 4-27. Hypersonic flow conditions.

continued to obtain more detailed information on the extent of the slip flow regime and its implications. (Fig. 4-27)

#### Applied Mathematics

Progress was made in research on literal symbol manipulation by a high-speed digital computer. The results of this work should make it easier to solve coupled sets of nonlinear ordinary and partial differential equations, where it is almost always necessary to resort to an approximation technique. The most commonly used approximation takes the form of a series expansion with an arbitrarily large number of terms, each having undetermined algebraic coefficients determined by inserting the assumed series into the governing differential equations. Since the success of the technique hinges upon obtaining many coefficients, the automation of the process of determining the algebraic coefficients makes it possible to obtain analytic approximations of much greater accuracy than previously possible. Programs developed in this research can be used to solve many classes of equations, including equations of motion of space vehicles and field equations of general relativity.

## Materials

*Stress-Corrosion.*—Titanium—the most efficient material for many aerospace structures—is used in pressure vessels for space vehicles. However, in this use, incompatibility between the titanium and the contained fluids was encountered. One of the most serious instances was the failure by stress-corrosion cracking (premature failure of a material subjected to a load) of titanium tanks containing methyl alcohol—a widely used and ordinarily bland fluid. After several failures, NASA began research on the stress-corrosion susceptibility of many different titanium alloys under many different conditions. One investigation of stress-corrosion cracking of titanium in methyl alcohol, revealed that a small amount of water in the alcohol could prevent stress-corrosion cracking; it also suggested that impurities in the alcohol might be causing stress-corrosion cracking. A test indicated that an incredibly small amount (3 parts per million) of hydrochloric acid can lead to early failures, and that the amount of impurities and the amount of the water inhibitor were extremely critical.

This research was not only very useful in pointing out ways to avoid stress-corrosion cracking by close control of the composition of the fluid that comes into contact with titanium but also valuable in offering possible insights into the basic underlying mechanisms of stress-corrosion cracking which are still almost totally unknown.

*Gas Bearings.*—Analytical and experimental work was continued on the concept of “lubricating” rotating machinery with a film of hot gas. The problem involved overcoming the major fault of gas bearings—unstable operation at low loads. Four solutions were developed: Cutting shallow herring-bone grooves in the bearing surface; placing adjustable tilting pads on that surface; pumping pressurized gas into the bearing; and constructing the bearing of metal foils whose flexibility provides automatic adjustment to the hydrodynamic conditions. The work made available several reliable and durable gas bearing designs for operation under various time, temperature, load, and speed conditions.

*Thin Films.*—Theoretical and experimental research on the atomic structure of metals by direct observation with field ion emission microscopy yielded quantitative information about the atomic arrangement at the surface and within the structure of metals. Direct observation of the dynamic processes involved in nucleation and growth of an evaporated thin film of gold on a tungsten surface showed that the number of nuclei from which a thin film of gold grows is dependent on a unique type of surface

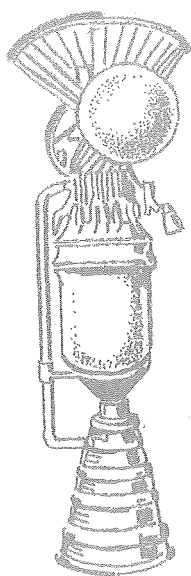
defect in the tungsten substrate. This kind of information should serve as the basis for greater control of technological processes such as gaseous absorption, oxidation, and the growth of thin films.

### Electrophysics

In NASA-supported research at the University of California (Berkeley), a second complex molecule, water ( $\text{H}_2\text{O}$ ), was discovered outside the solar system by Nobelist Charles H. Townes. (*20th Semiannual Report*, p. 133) The intense microwave radiation from the water molecules at a wavelength of 1.35 cm was found by scanning the Orion Nebula and some other galactic sources with a 20-foot radio telescope equipped with specially designed receiving equipment which provided a spectral resolution of 1.3  $\text{MHz}$ , or better than 1 part in  $10^4$ . By repeated scanning across Orion, it was determined that this intense source is comparatively small, having a diameter not larger than about 3 minutes of arc. The microwave brightness of the Orion radiation appears to be several hundred degrees K and may be a thousand degrees or more, indicating that the molecules are not in thermal equilibrium and that stimulated emission or maser action may be present. Research on the distribution and characteristics of  $\text{H}_2\text{O}$  in interstellar space is continuing since it is not obvious how excitation to higher energy levels takes place and especially how maser amplification can take place in space. The high intensity of the radiation shows that the excitation is occurring in regions where much cosmic energy is being released. This could be due either to gravitational contraction of gas and dust or to other sources of rapid heating involved in stellar formation or activity. In addition to its astronomical interest, the radiation provides a good point source for antenna calibration, and for measuring atmospheric microwave attenuation due to water vapor content of the atmosphere.

Extremely pure niobium nitride ( $\text{NbN}$ ) thin-film (1,000 Angstroms) superconductors capable of maintaining an extremely high magnetic field, greater than 225 kilogauss, were produced under NASA contract. This was the first successful effort to produce ultra-pure thin films of  $\text{NbN}$  which is one of the transition metal compounds with a comparatively high transition temperature in bulk form and consequent presumably high transition temperatures and high magnetic field capabilities in the thin film form. The  $\text{NbN}$  thin films were produced by reactive sputtering of a niobium cathode in an atmosphere of argon and nitrogen under ultra high vacuum conditions.

Tests of the NbN thin film superconductor at liquid helium temperature showed that it will support magnetic fields equal to or better than niobium tin ( $\text{Nb}_3\text{Sn}$ ) currently the highest field material. However,  $\text{Nb}_3\text{Sn}$  is difficult to produce and expensive as a ribbon for magnet coil windings while niobium nitride can be made reproducibly in continuous thin films of uniform thickness for coil windings at lower cost. This research may, therefore, result in a new extremely high field niobium nitride superconductor which is more stable and much easier to manufacture than niobium tin. Because superconducting magnets produce intense magnetic fields in a small volume of low weight, they have excellent potential uses in space power and propulsion systems and shielding spacecraft from damage by high energy charged particles. Research is continuing to determine why niobium nitride in thin film form maintains its superconducting state in the presence of such extremely high fields.



5

## THE NUCLEAR ROCKET PROGRAM

Substantial progress was made in furtherance of the nuclear rocket program objectives during the first half of 1969. The most significant activity was the testing in Engine Test Stand No. 1 of the ground-experimental engine with components arranged as in a flight engine. A series of experiments to investigate the engine startup and dynamic characteristics was successfully completed, and the engine was operated at full thrust (about 55,000 pounds).

### NERVA Engine System Technology Status

The ground-experimental engine (XE) test program is the last activity to be completed in the NERVA engine system technology phase of the nuclear rocket program. NERVA effort will hereafter concentrate on development of the 75,000-pound-thrust flight engine.

The principal objectives of the XE test program are to investigate the operational features of the engine test facility systems, the character of the engine and facility for self-activating starts, and means of controlling the engine while starting, holding steady, and shutting down; and to obtain steady-state performance data during operations under various powers, temperatures, and flow rates.

These objectives relate to NERVA development because of similarities in hardware, characteristics, and environments between XE and the flight engine. They are also important because of interactions between engine and test stand since ETS-1, with some modification, will continue to be used in NERVA development. Facility systems and engine systems must be operated together in order to obtain valid and productive test experience. Operating modes and control-system designs for NERVA will also evolve from the XE investigations, and extensive measurements will be made of component environments for use in NERVA design.

In March, following the reinstallation of the XE engine in Engine Test Stand No. 1 (*20th Semiannual Report*, p. 139), the next planned series of experiments on the XE engine was initiated. In the experiments, designed to demonstrate a selected mode of engine bootstrap (self-activating) startup, the engine was successfully started three times. Engine power and the flow of liquid hydrogen through the engine increased smoothly, and engine control was satisfactory.

In May, an attempt was made to bootstrap start the XE engine for a series of experiments at the intermediate and full power levels. In this test, the engine turbopump failed to rotate, making it necessary to postpone the experiment until the cause of the higher than normal friction forces on the turbopump rotor was determined. On the basis of the data from these attempts and examination of the engine on the stand, it was decided to replace the turbopump. Investigation revealed that the friction problem was a minor one due to rubbing of a seal. The seal clearance was increased on the replacement pump, and in June the XE test program was resumed.

In a 12-minute test on June 11, the engine was operated for approximately 3.5 minutes at full power. The test was a milestone in the nuclear rocket program, for it was the first time a nuclear rocket engine was operated at full power or started under simulated altitude conditions, and it was also the first full-power test in Engine Test Stand No. 1, the only facility capable of testing nuclear rocket engines in a simulated high-altitude environment. (Fig. 5-1.)

On June 26, the XE engine was run through a series of control experiments and wet and dry autostarts. In the latter, the objective was to bring the engine from the shutdown condition into the operating region without utilizing the nuclear instrumentation system for control. The dry autostarts were generally successful and demonstrated a start-up mode that was smooth throughout the

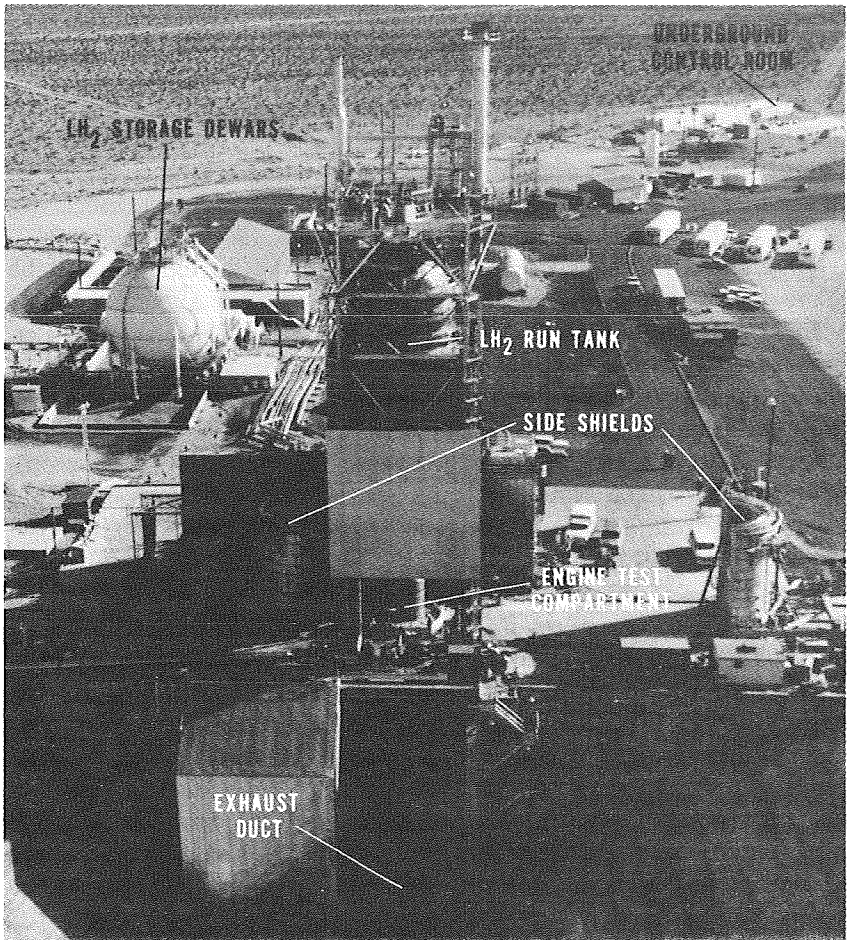


Fig. 5-1. Engine Test Stand Number 1.

initial turbopump transient. The tests gave data on proper controller settings to achieve a full range of start-up capability under nearly all conditions.

#### NERVA Development Status

NERVA engine design development work concentrated on a systematic study of flight-engine design requirements, and on studies to determine the best way of meeting these requirements and how meeting them would influence the engine design.

In conjunction with this system engineering activity, work continued on the detail design of the reactor and engine, and on com-

ponent development where funds and manpower permitted. Adjustments were being made in the design to accommodate an adequate light-weight shield; an efficient, thoroughly safe, and reliable propellant feed system; a high reliability reactor control system; and an efficient reliable nozzle suitable for extended operation and multiple cycle duty. The concentrated effort being applied to these areas is intended to provide a highly-reliable engine system with high performance.

## SUPPORTING RESEARCH AND TECHNOLOGY

### Fuel Element Materials Research

A continuing objective of this program is to improve the temperature, power density, duration, and recycling capability of nuclear rocket fuel elements—improvements directly transferrable into meaningful gains in space vehicle performance. Most of the effort is devoted to development of corrosion resistant coatings for fueled graphite and graphite-carbide composite materials and investigation of all carbide fuel elements. Other work involves research on the mechanism of corrosive attack, the microstructure of coatings, and on improved means for assessing coating integrity.

As part of the fuel-element technology effort, the first Pewee reactor, the Pewee-1, was tested in a series completed on December 4, 1968, only 19 months after the detailed design of the reactor was initiated. (*20th Semiannual Report*, p. 137.) Pewee-1 set records in power density and temperature for nuclear rocket reactors or any other reactor. Its power density was 20 percent higher than that of Phoebus-2A and approximately 50 percent above the power density required for the 1,500 megawatt NERVA reactor. The steady state fuel element gas temperature of Pewee-1 exceeded the levels achieved previously in the NRX reactor tests by nearly 300°F.

In terms of thermal and nuclear performance, the first Pewee reactor operated very close to planned conditions with only some moderate departures from design in reflector temperatures. Consequently, the Pewee reactor concept was considered qualified for use in fuel element testing, and as having met the major objective of the Pewee-1 reactor test.

As a test bed, Pewee-1 was also used for fuel element experiments investigating the combined effects of new coating techniques, modifications of the graphite matrix, and improved coated fuel particles. The results are undergoing detailed study and examination.

A second Pewee reactor, the Pewee-2, now being readied for testing, will be used to test prime fuel-element candidates for the R-1 NERVA development reactor. The Pewee-2 reactor will be operated in as many as six ten-minute full-power cycles separated by short holds at low power. Additional Pewee reactor tests will demonstrate fuel concepts for achieving longer durations, and higher temperatures, power densities, and propellant flows.

Electrical resistance tests have been used for fuel element development and quality assurance testing, but they have become less and less satisfactory as fuel element temperatures reach higher and higher levels. To resolve this problem, the Los Alamos Scientific Laboratory designed a reactor concept, the "nuclear furnace," able to test 50 fuel elements at a time with a short turn around time between tests. This device should partially replace the electrical tests in the fuel element development sequence, reduce the frequency of testing Pewee reactors, and improve the information yield from Pewee tests because of superior prior knowledge.

#### Nuclear Stage Technology

Because nuclear-rocket stage technology is mostly the same as that for a cryogenic chemical-rocket stage, stage technology work conducted in the nuclear rocket program stresses problems unique to nuclear propulsion or nuclear rocket missions.

An experiment to measure propellant heating by nuclear radiation was in the engineering design and analysis phase. In the first part of this experiment an available test tank will be used to check out instrumentation and insulation systems which are to be used in the actual propellant heating test tank. In the second part, the specially constructed propellant heating test tank will be tested with flowing hydrogen. (Fig. 5-2.)

In other work directed toward developing a nuclear stage to be powered by NERVA, contracts were let for stage studies which will provide detailed analyses, conceptual designs, and development requirements for a versatile nuclear flight propulsion system. The stage studies will also provide information needed to proceed with the development of the NERVA engine.

#### Advanced Nuclear Rocket Concepts

Research continued on a gas-core concept which does not restrict the peak reactor temperature as does a solid material. With the fissionable fuel in a gaseous state, it should be possible to attain specific impulse values three times those of solid-core systems. Research in the last two years emphasized the closed-cycle system—

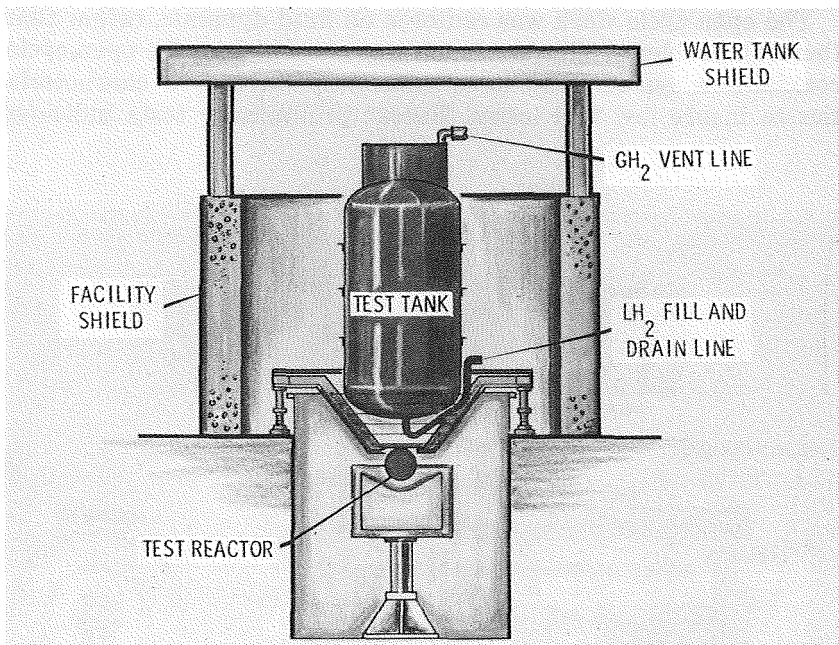
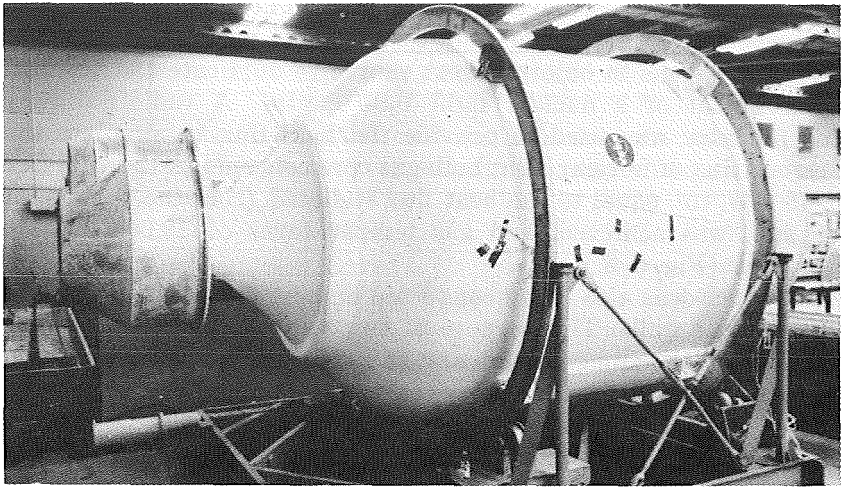


Fig. 5-2. The test tank (top) and test configuration concept.

one in which a transparent physical barrier is used to contain the fuel. Such a system may make it easier to achieve the necessary fuel containment; however, since its feasibility has not yet been shown, work also continued on open cycle concepts.

Work on the closed-cycle system (the light-bulb reactor) was concerned largely with the high temperature portions of the concepts, and seeks to obtain a heat source to duplicate the thermal environment of a nuclear light bulb engine. A radiofrequency (RF) heater was used to provide the heat flux to simulate the thermal flux of nuclear light bulb gas core concepts. A thermal flux of 35 KW/in<sup>2</sup>, equal to the heat flux radiated from the surface of the sun, was achieved, and gas temperatures of 18,000°F were observed. (Fig. 5-3.)

Research was also being conducted on how radiation affects the transparent walls. The purpose of this work is to determine the rates at which damage occurs and at which the damage is annealed out in the candidate materials so as to decide whether transparent materials will survive in the gas core environments. A modest amount of fluid dynamic research relating to the gas core was continued, and analytical studies of the dynamic and transient characteristics of the gas core were started.

The open cycle work was centered on fluid dynamic, rather than thermal, problems. This approach was chosen since the open-cycle, coaxial-flow system must have sufficiently stable flow characteristics to insure low fuel losses. Recent preliminary tests indicated

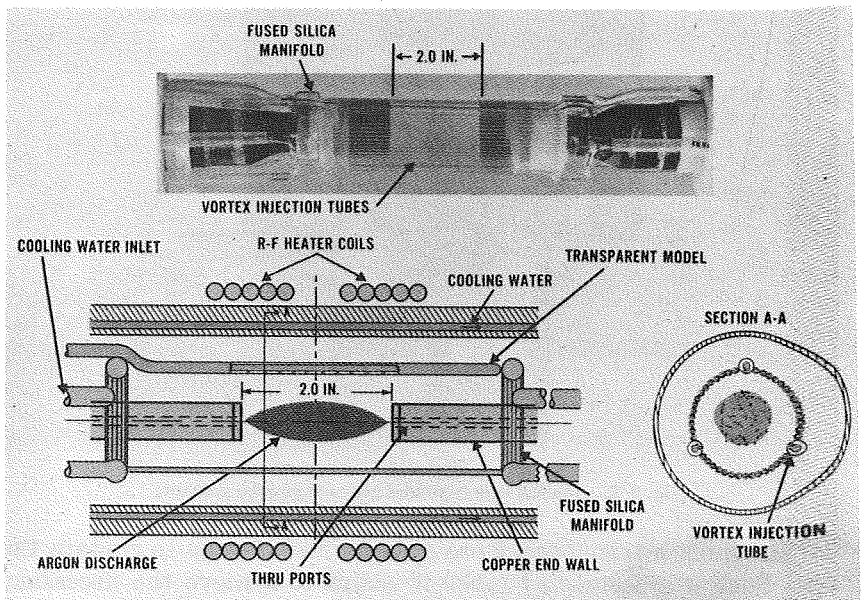
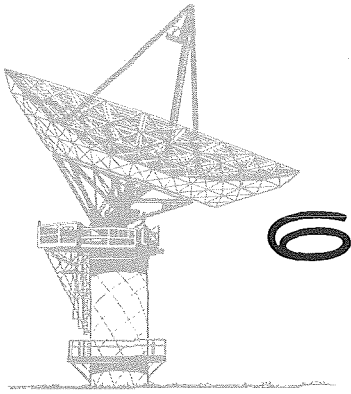


Fig. 5-3. Transparent wall model test method.

the possibility of developing fuel and propellant injection systems which will give stable coaxial-flow streams at low temperature. The tests suggest that acceptably low uranium loss rates may be achieved in this concept.



## TRACKING AND DATA ACQUISITION

The operational support activities of the NASA tracking and data acquisition networks continued at a high level. In addition to covering on-going space missions, the networks supported 17 new flight projects launched during this period.

The diversity of the networks' capabilities was illustrated by the major missions launched and supported. These included the Mariner VI and VII flyby missions to the planet Mars; an advanced meteorological earth-orbital satellite, Nimbus III; and, of course, the two highly successful manned missions, Apollo 9 and 10.

### MANNED SPACE FLIGHT NETWORK

The Manned Space Flight Network continued to provide vital support to the Apollo Program, clearly demonstrating during the Apollo 9 and 10 missions that it could meet the requirements of the lunar landing and return mission, currently planned to occur on Apollo 11.

The Apollo 9 mission, which included the first manned flight of the Lunar Module, placed very demanding requirements upon the network, calling for simultaneous support of two manned spacecraft—the LM and the CSM. Although the network had furnished such simultaneous support in the past (the Gemini 6 and 7 rendezvous missions), the maneuvers performed by the LM and CSM were the most complex to date, and required network support of the two craft as they flew separately for a record time of more than six hours.

The success of the Apollo 10 mission, launched May 18, highlighted again the vital relationship of the network to the Apollo lunar landing program. Not only did it furnish flawless naviga-

tional support; it also maintained perfect communications across some 250,000 miles of space. Additionally, it received and relayed dramatic color TV pictures of the moon. (Fig. 6-1.)

As the LM and CSM undocked, the network stations began simultaneous support of the two manned spacecraft. Precision tracking kept flight controllers in the Mission Control Center at Houston continuously aware of the position of each spacecraft as the LM left the CSM and descended within ten miles of the lunar surface. (Fig. 6-2.) The stream of data and high quality voice communications received by the network's worldwide system of stations during the LM flight enabled the flight controllers and astronauts Stafford and Cernan to work together in the complex maneuvers needed to assure the safe return of the LM to the CSM.

Throughout the entire mission, the network met all require-

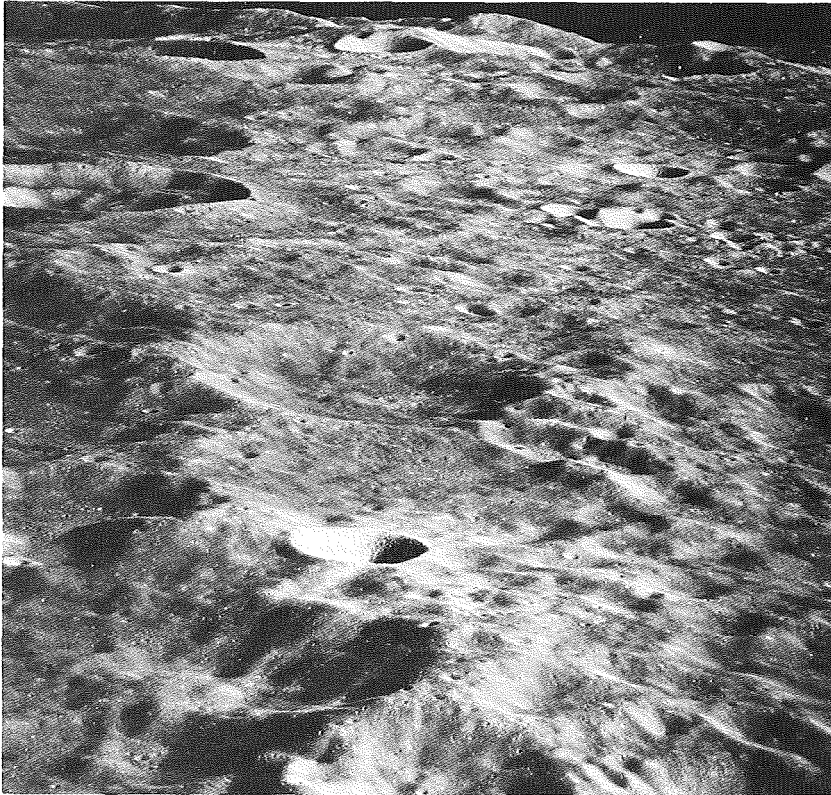


Fig. 6-1. Moon's surface photographed from Apollo 10.

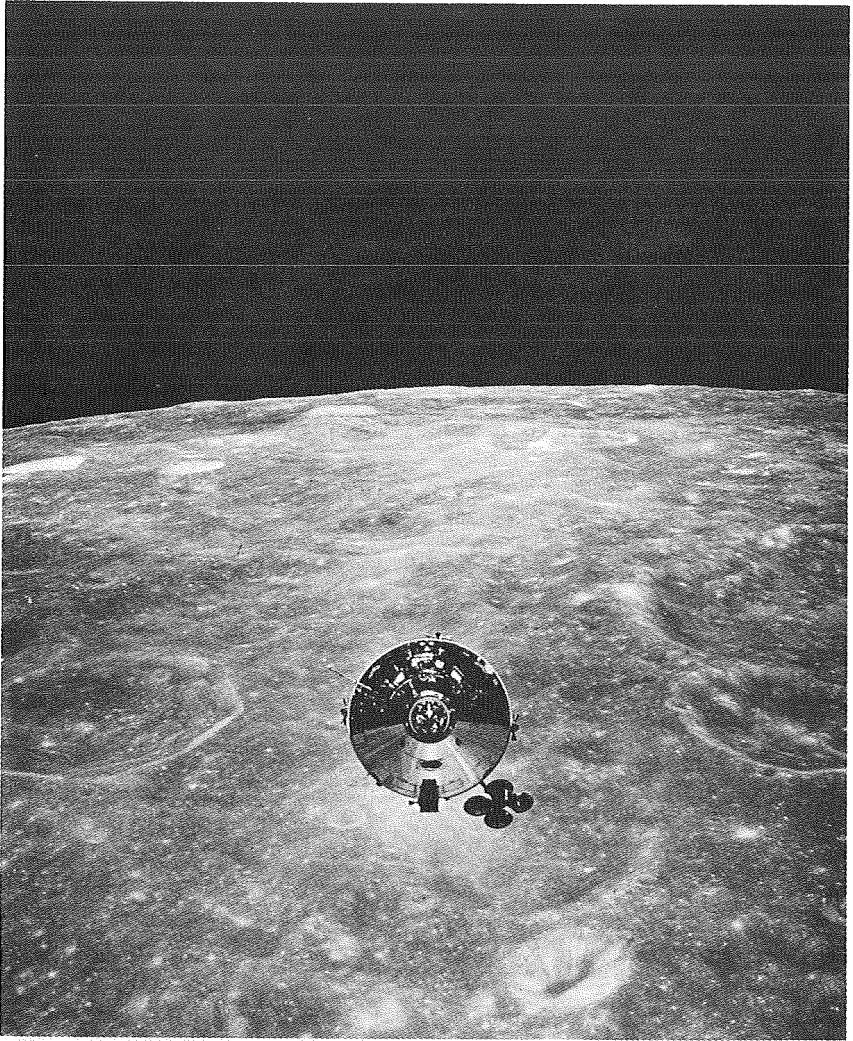


Fig. 6-2. CSM viewed from the LM during Apollo 10 mission.

ments, including the accurate tracking and communications needed to assure the precision return to the earth of the spacecraft and the safe recovery of the astronauts.

### SATELLITE NETWORK

The Satellite Network also continued to carry out its tracking and data acquisition assignments. In addition to covering all of

NASA's scientific and applications programs, the network supports a wide variety of space projects conducted by other Government agencies (Department of Defense and the Environmental Science Services Administration), by private industry (Communications Satellite Corporation), and through cooperative international programs.

The network supported 13 spacecraft launched during the period (listed below) and provided daily coverage to an average of about 40 active satellites launched previously.

<i>Mission</i>	<i>Date Launched</i>
OSO-V	January 22
ISIS-I	January 30
Intelstat III F-3*	February 5
ESSA-IX**	February 26
Nimbus III	April 14
EGRS-13**	April 14
Intelstat III F-4*	May 21
EGRS-29**	May 23
OV5-6**	May 23
OV5-9**	May 23
OGO-VI	June 5
IMP-G	June 21
Biosatellite III	June 28

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\*Communications Satellite Corporation (PanSat)

\*\*Scientific satellites of other Government agencies.

The network furnished support to these missions through the electronic facilities of the Space Tracking and Data Acquisition Network (STADAN), operated under the management of the Goddard Space Flight Center, Greenbelt, Maryland. The STADAN stations are aided by a worldwide optical network of precision camera stations operated by the Smithsonian Astrophysical Observatory.

One of the major flight projects of the period was Nimbus III, a butterfly-shaped satellite weighing nearly 1,300 pounds—a record for meteorological satellites. Carrying seven meteorological experiments, the versatile Nimbus observatory became the first weather satellite to measure emitted infrared energy that enables scientists to determine the atmosphere's vertical temperature, water vapor, and ozone distributions on a global basis. These data, collected by the STADAN stations, are some of the key ingredients needed for computerized weather predictions. Also, the network partici-

pated in the Apollo 9 and 10 missions by placing priority support on selected in-orbit spacecraft. The satellites, such as the IMP-D and ATS-III, provided vital proton monitoring information during the Apollo missions. The network stations relayed the information to the Mission Control Center at Houston, Texas (Fig. 6-3), and the Space Disturbance Forecast Center at Boulder, Colorado, enabling the flight controllers to monitor the radiation levels which the astronauts were exposed to.

The bioscience satellite (BIOS-III) launched on June 28, placed stringent real-time support requirements on STADAN. The presence of the primate, a pigtail monkey named Bonny, aboard BIOS required almost continuous and immediate monitoring of the animal's condition and environment. Relevant information received at STADAN's most remote sites was sent to the Goddard Space Flight Center for diagnosis and decision as necessary. In addition, the STADAN maintained a constant readiness to call down BIOS should an early abort become necessary.

Network support of NASA's passive communications satellite program ended when the Echo II "balloon" satellite reentered the earth's atmosphere and decayed on June 7. (Fig. 6-4.) The network maintained contact with Echo II throughout its five and one-half-year lifetime, providing the news media with daily predic-

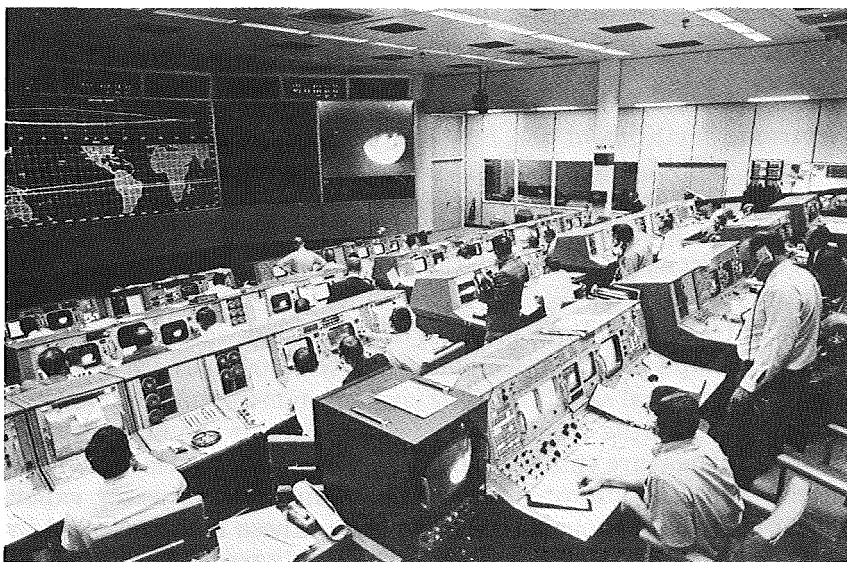


Fig. 6-3. Mission Operation Control Room of MSC, Houston, Texas.

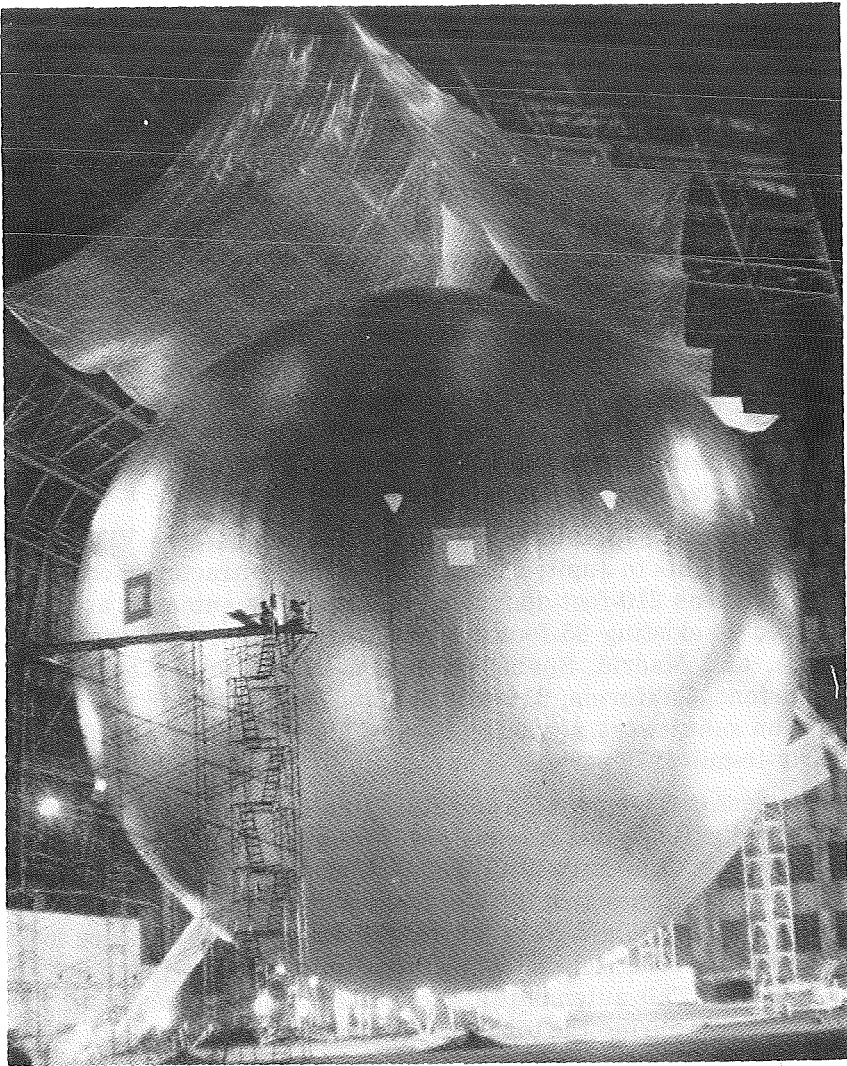


Fig. 6-4. Echo II "balloon" satellite before launch.

tions indicating where and when the satellite would pass. After its launch in January 1964, the satellite served NASA, other Government agencies, and universities for more than a year as a reflector for "bouncing" radio transmissions from one ground point to another—even to intercontinental distances. Equally as important, the satellite provided an important space target for geophysicists who used it for geodetic studies.

## DEEP SPACE NETWORK

The Deep Space Network supported four on-going Pioneer missions—Pioneer VI, VII, VIII, and IX—as well as the launch, mid-course and cruise phases of the Mariner VI and VII missions. (p. 57) The latter two spacecraft were being monitored and controlled by the network as they sped toward Mars on their 190 million-plus-mile trip. The network will receive television transmissions during the flyby period and, in addition, will use the Goldstone 210-foot antenna to receive numerous far-encounter views of Mars as the spacecraft approach the planet.

With the data received from these missions and that expected from the planned Mariner '71 flight, NASA hopes to determine whether or not the planet's environment is suitable for supporting life. More definitive data concerning the question of Martian life will be obtained when the Viking mission, scheduled for launch in 1973, will land two payloads on the planet.

In preparing for future planetary missions such as Viking and Pioneer flights to Jupiter, NASA selected a contractor to construct two overseas 210-foot-diameter antennas. The antennas are to be located at existing 85-foot antenna stations near Canberra, Australia, and Madrid, Spain; these, together with the operational Goldstone, California, 210-foot antenna, will complete the ground station subnetwork needed to support the missions planned in the early-to-mid 1970 period.

Besides carrying out its planetary unmanned missions responsibilities, the Goldstone antenna also furnished support to the Apollo 10 mission. The huge 210-foot system, with a communications capacity six times that of the 85-foot standard antennas of the Manned Space Flight Network, contributed in large measure to the remarkable color television pictures of the moon taken by the Apollo 10. (This antenna is also expected to play a prominent role, particularly during the touchdown and liftoff phases, in support of the Apollo 11 lunar landing.)

To permit television reception while the Apollo 11 astronauts walk on the moon's surface, arrangements were made for the use of the Parkes 210-foot radio astronomy antenna in Australia (Fig. 6-5). The arrangements were made through the cooperation of the Australian Commonwealth Scientific and Industrial Research Organization which agreed to suspend its regular radio astronomy activities during the mission and permitted the temporary installation of special equipment on the antenna.

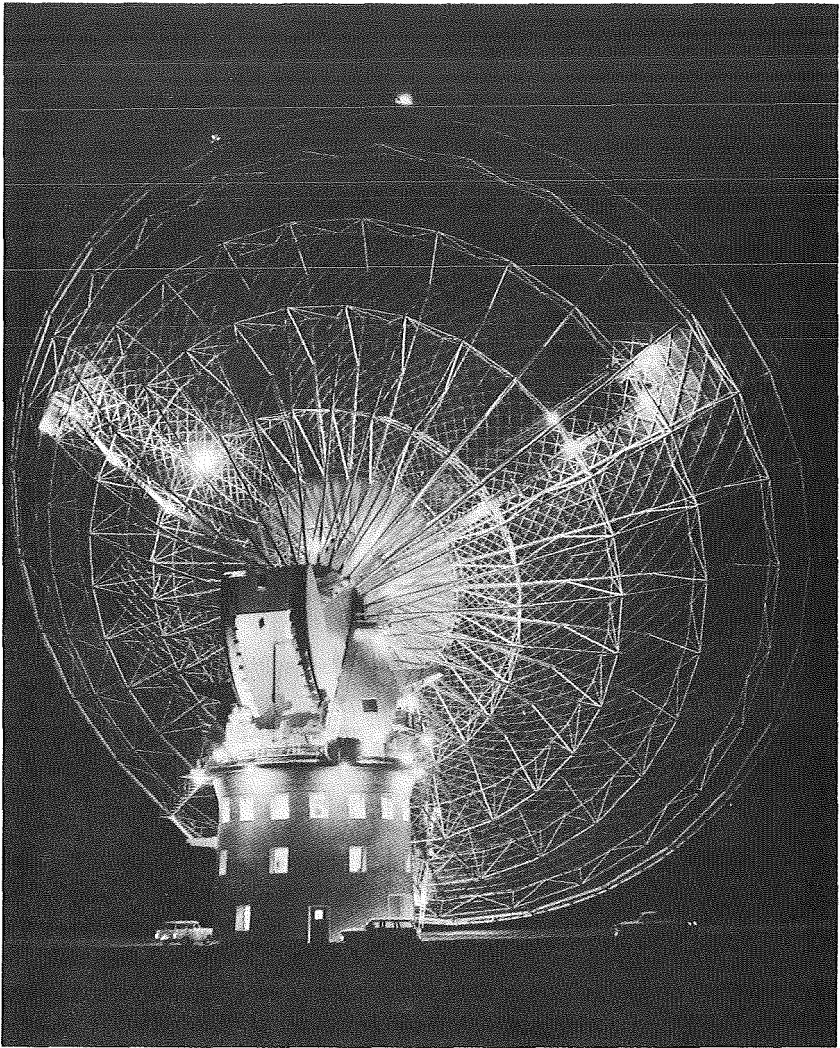


Fig. 6-5. Parkes 210-foot antenna, Australia.

### NASA COMMUNICATIONS SYSTEM

The NASA Communications System (NASCOM) is a worldwide network of operational lines and facilities designed to permit circuit-sharing and flexibility among all the NASA tracking facilities. The NASCOM carries mission-related information for all NASA programs and for other agencies' projects supported by NASA. (Fig. 6-6.)

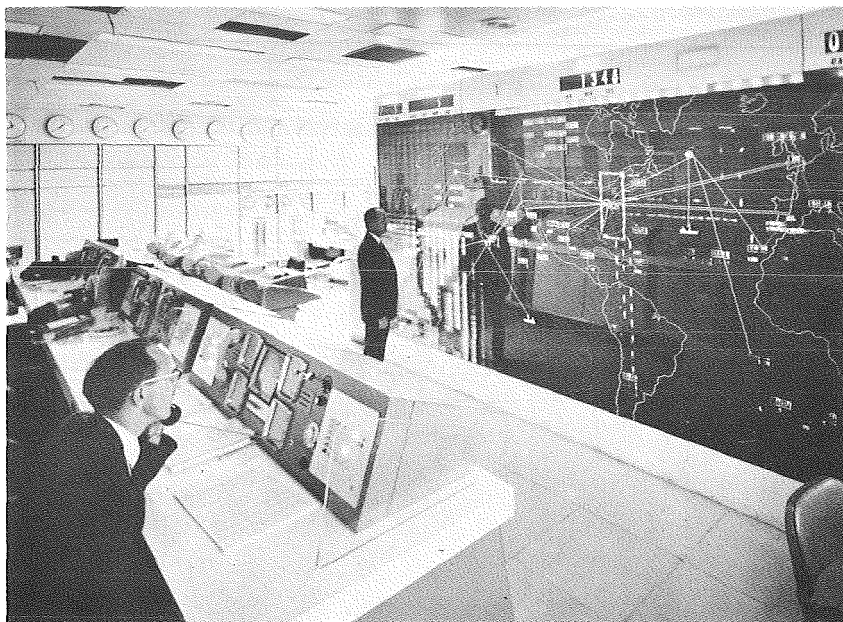
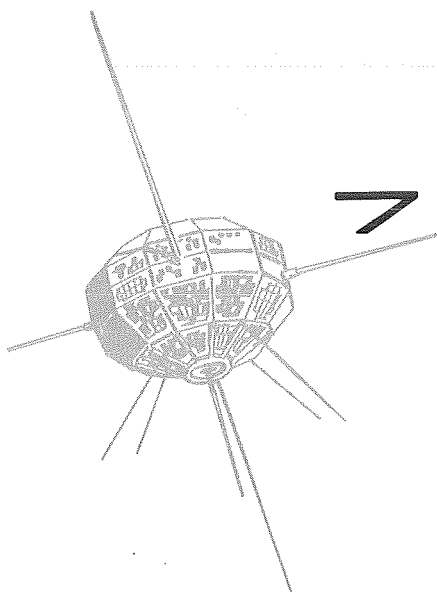


Fig. 6-6. The NASA Communications System (NASCOM).

During this period, a new mode of international communications was introduced between the Goddard Space Flight Center and the NASA tracking complex in Spain. The service consists of a wide-band (48 KHz) channel via communications satellite. The new service takes advantage of communication satellite technology and permits the link to be used as a single wideband (multi) channel or subdivided into greater numbers of individual voice and teletype channels. This arrangement allows NASA to adjust the link to meet varied program communications needs and thereby obtain the utmost flexibility at substantial cost savings.



## INTERNATIONAL AFFAIRS

New cooperative space and aeronautics projects and support activities extended NASA's international program. The NASA Administrator emphasized the continuing interest of the United States in multilateral and bilateral space activities during his visit to Europe in June.

### COOPERATIVE PROJECTS

International cooperation between NASA and foreign space agencies was highlighted by NASA's launching of the Canadian ISIS I satellite (International Satellite for Ionospheric Studies); agreements with Germany on two advanced solar probes (Project Helios) and an aeronomy satellite (Aeros II); an agreement with the United Kingdom for an ionospheric particle and radio noise satellite (UK #4); the launching of three foreign experiments (two French, one British); an agreement for a British experiment on the Nimbus E satellite; and the selection of six foreign experiments for flight on the 1969 auroral and 1970 solar eclipse expeditions. Also, NASA continued its cooperation in sounding rocket work. An additional foreign scientist was selected to take part in the study of Apollo lunar samples when they become available.

#### Canada

As part of the joint Canada-U.S. program of ionospheric re-

search, NASA launched the International Satellite for Ionospheric Studies (ISIS-I) on January 30. In this satellite, instrumentation for direct measurements are combined with a topside sounder to measure significant ionospheric phenomena at the same time and in the same location in space. (Figs. 7-1 and 7-2.)

This Canadian-built satellite is Canada's third in a total of five in a cooperative series with NASA. It continues the study of the ionosphere that began with the Canadian-built, NASA-launched Alouette I satellite which is still returning data after more than six years in orbit.

### Germany

The NASA Administrator and the German Minister for Scientific Research signed two Memoranda of Understanding for the Helios and Aeros projects in Bonn (June 10, 1969). Helios is the most advanced international scientific space probe yet undertaken. It consists of a pair of solar probes which will carry ten scientific experiments closer to the sun than any spacecraft so far scheduled. These probes will be launched in the 1974-75 period. The scientific objectives of the Helios probes are to provide new understanding

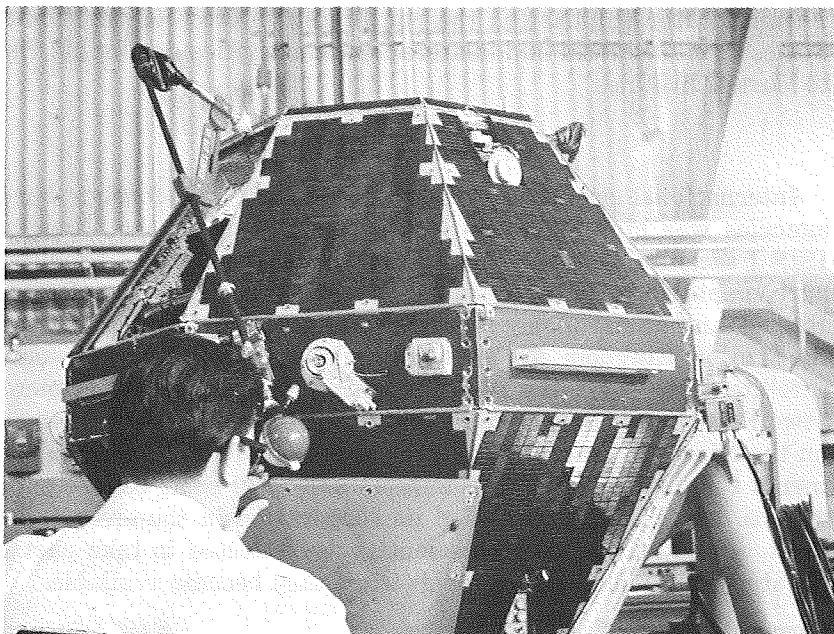


Fig. 7-1. Checking out ISIS-I.

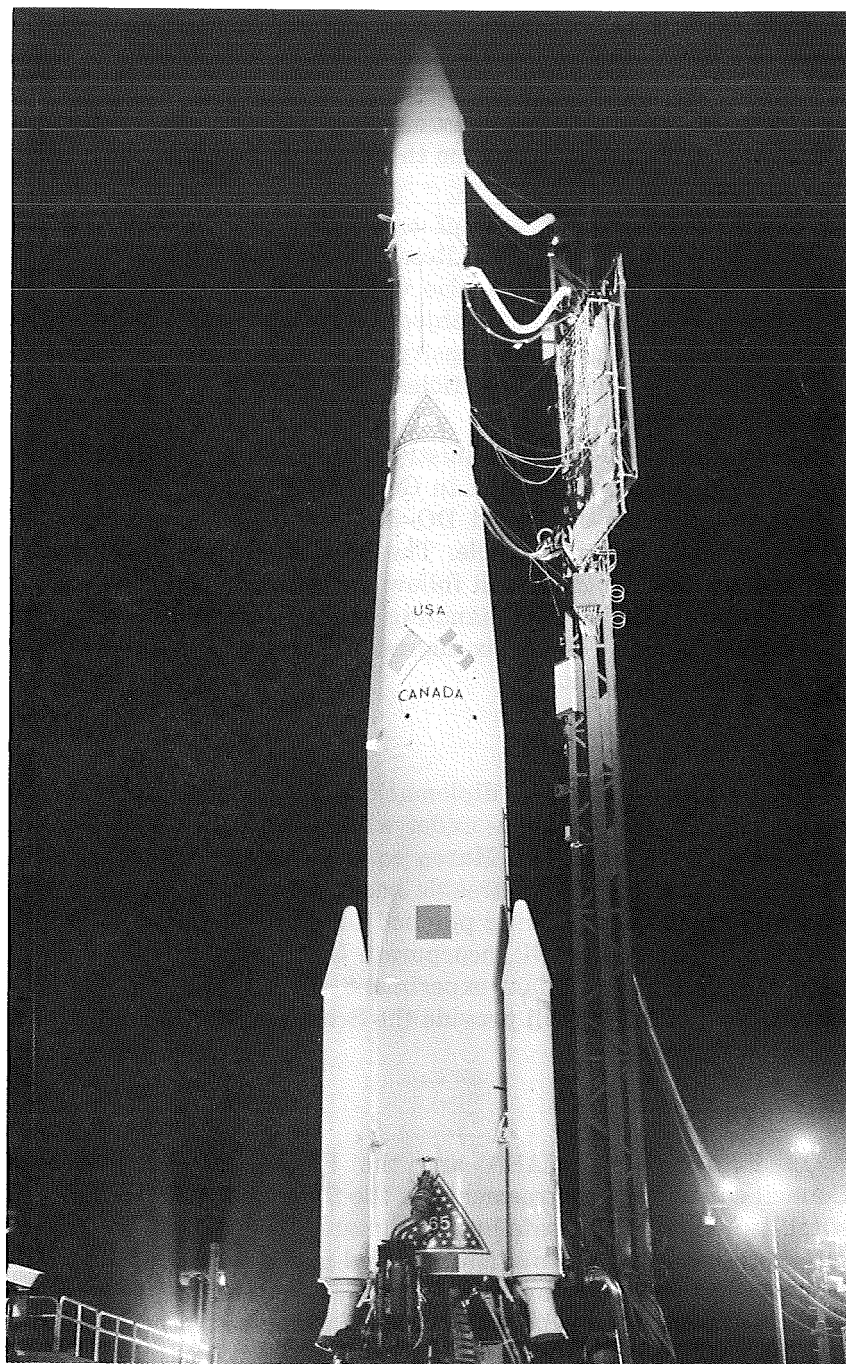


Fig. 7-2. ISIS-I launch vehicle.

of fundamental solar processes and sun-earth relationships by studying the solar wind, magnetic and electric fields, cosmic rays, and cosmic dust. The German Ministry for Scientific Research will be responsible for building the two spacecraft and seven of the ten experiments. NASA will provide the launches and the other three experiments.

The Aeros project consists of a spacecraft to be built by the German Ministry for Scientific Research and launched on a NASA Scout rocket in 1972. NASA also will provide an experiment for this spacecraft. The scientific objective of the project is to correlate local upper atmosphere density and temperature variables of neutral particles, charged particles, and solar ultraviolet flux in selected wave lengths.

NASA and the German Ministry for Scientific Research have agreed in principle to conduct in Germany a joint flight program to test the German-developed DO-31 aircraft, a jet-powered advanced VTOL research vehicle. The 12½ hours of flight testing planned for this program will follow a previously conducted study of the stability, control, and handling qualities of the aircraft being carried out on the NASA six-degree-of-freedom simulator at the Ames Research Center.

#### Italy

Through an exchange of diplomatic notes in June, the U.S. and Italy agreed to the principles under which Italy will supply launching services from the San Marco equatorial platform for NASA spacecraft on a cost reimbursable basis. Launching in early 1970 from the platform was being planned for the Italian San Marco C satellite. This satellite will incorporate U.S. instrumentation along with the primary Italian experiment for atmospheric density measurement. NASA will provide the Scout launch vehicle for this cooperative project.

#### United Kingdom

On February 14, NASA and the British Science Research Council concluded an agreement for the fourth cooperative US/UK satellite project. The satellite, designated UK #4, is to explore interactions among the plasma, charged particle streams, and electromagnetic waves in the topside ionosphere. Launch on a NASA Scout vehicle is planned for 1971. The British will provide four of the five experiments. The fifth is to be a NASA-sponsored experiment from the University of Iowa.

A selective chopper radiometer proposed by the Universities of Reading and Oxford has been chosen for flight on the Nimbus E meteorological satellite, scheduled for launching in 1972. This experiment is expected to measure water vapor, cloud, and atmospheric temperature. Similar instrumentation also prepared by the Reading/Oxford group is scheduled to be flown in 1970 on Nimbus D.

#### Lunar Sample Program

Two foreign principal investigators were added to the list of those selected to participate in the analysis of lunar samples returned in the Apollo program. Totals now stand at 36 foreign principal investigators from eight countries and twenty institutions.

#### Foreign Experiments Flown on OSO-V and OGO-VI

Three foreign experiments were carried on two NASA satellites launched during the first half of 1969. French and British experiments were carried by OSO-V, launched in January to conduct coordinated experiments in solar physics, astronomy, and geophysics. A French experiment was carried by OGO-VI, launched in June to conduct investigations of geophysical and solar-terrestrial phenomena.

#### Orbiting Astronomical Observatory

Two scientists from the Netherlands were selected to participate as "Guest Observers" on the Orbiting Astronomical Observatory (OAO-II) launched in December 1968.

#### Earth Resources Survey

In the cooperative earth resources survey projects with Mexico and Brazil, a NASA remote sensing aircraft completed flights over the Mexican test sites in April. At the end of the period, plans for flights over the Brazilian test sites were being completed. Data from these flights will be analyzed for promising earth resources applications in Brazil and Mexico. They should contribute to the development of techniques and systems for surveying earth resources from aircraft and spacecraft.

#### Airborne Auroral and Eclipse Expeditions

Between ten and fourteen NASA aircraft flights were being planned for November and December, 1969, to study auroras in

northern latitudes, particularly in regions where the sun remains below the horizon throughout the day. Three foreign scientists, two from Canada and one from France, were selected to join nine U.S. scientists on the flights.

The same NASA aircraft will be used to carry out experiments during the March 7, 1970, total eclipse of the sun. Ten investigator groups—including scientists from Canada, Greece, and Italy—have been selected to participate in the flight along the path of the eclipse.

#### **Sounding Rocket Projects**

NASA made four new cooperative sounding rocket agreements during the first half of 1969, and began to expand one existing agreement. Five countries (Brazil, India, Japan, Sweden, and the United Kingdom) entered into cooperative agreements with NASA. Included were tripartite agreements with Sweden and the United Kingdom, and with India and Japan.

Seven countries (Argentina, Brazil, Canada, India, Japan, Spain, and Sweden) conducted cooperative sounding rocket projects under existing or new agreements with NASA. Among the investigations performed were coordinated launchings to study the structure and behavior of the atmosphere, to examine atmospheric and ionospheric phenomena in the auroral zone, to conduct radio propagation experiments near the geomagnetic equator, and to investigate discrete celestial X-ray sources in the southern hemisphere.

### **UNITED NATIONS**

The Director of Space Applications served as U.S. Representative to the United Nations Working Group on Direct Broadcast Satellites, which met at United Nations Headquarters in New York (February 11–20, 1969).

The Assistant Administrator for International Affairs served as U.S. Representative to the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space during its meeting at United Nations Headquarters March 17–28, 1969.

### **OPERATIONS SUPPORT**

NASA continued to receive valuable operations support from abroad. Spain extended until January 29, 1984, its agreement permitting NASA to maintain a tracking station at Madrid. The ex-

tension cleared the way for NASA to establish a 210-foot-diameter antenna for support of future deep space probes, beginning with the Mars missions in 1973. Responsibility for operations of one of the 85-foot antenna deep space facilities at Madrid was transferred to the Instituto Nacional de Tecnica Aeroespacial (INTA), the cooperative agency for this station. (Fig. 7-3.)

Discussions are under way with Australia concerning the addition of a similar 210-foot deep space antenna at the Canberra station. NASA plans to close the Applications Technology Satellite ground station at Cooby Creek, Australia, after the launch of ATS-E, subject to temporary utilization by Australia for experiments with ATS-1.

Arrangements were completed with the British and Japanese for data acquisition from Biosatellite-D by stations at Singapore and Kashima. Ireland approved the staging of two NASA aircraft to conduct sea-state measurements over the northern Atlantic. Additionally, many countries continued to support the Apollo program by granting staging or overflight rights for astronaut recovery aircraft and Apollo/Range Instrumentation Aircraft.

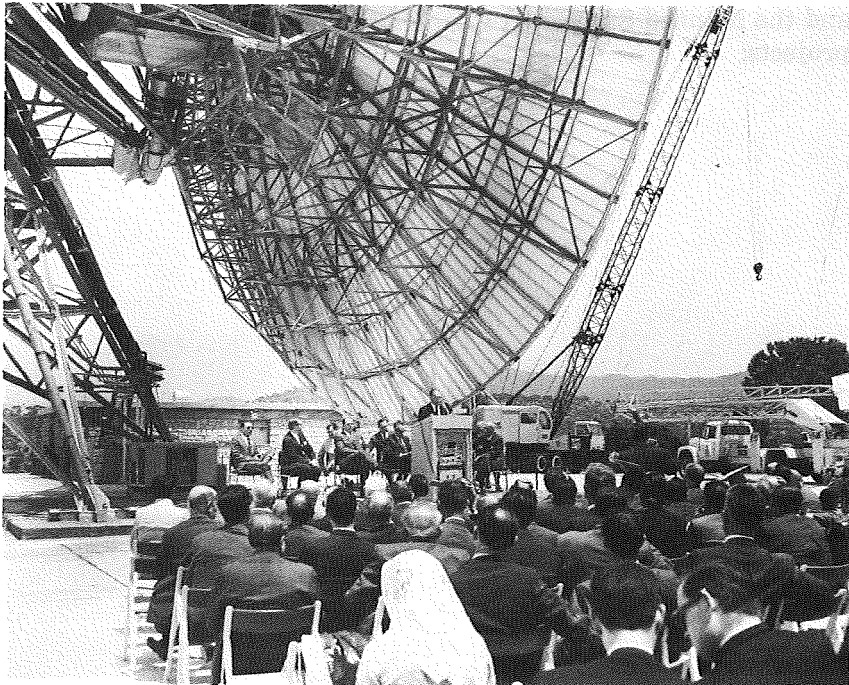


Fig. 7-3. June 14 ceremony marking transfer of responsibility to INTA.

NASA participated in an auroral research balloon flight project from Iceland sponsored by the National Science Foundation.

### PERSONNEL EXCHANGES, EDUCATION, AND TRAINING

During the first half of 1969, 2,000 foreign nationals from 75 locations visited NASA facilities for scientific and technical discussions or general orientation.

Under the NASA International University Fellowship Program, 53 students from ten nations were engaged in graduate study at 19 American universities. They were supported by their national space research sponsors or by ESRO. This program is administered for NASA by the National Academy of Sciences.

One hundred and three postdoctoral and senior postdoctoral associates from 18 nations carried on advanced research at NASA centers, including the Jet Propulsion Laboratory. This program, also administered by the National Academy of Sciences, is open to both U.S. and foreign nationals.

Thirty-four scientists, engineers, and technicians from Australia, Japan and Germany—here at their own expense—received training in space technology at the Goddard Space Flight Center and the Manned Spacecraft Center in connection with cooperative projects.



## UNIVERSITY PROGRAMS

### SUSTAINING UNIVERSITY PROGRAM

This Program supports university activities broader in scope and longer in range than the project-oriented research supported by other NASA elements. It enables NASA to make use of qualified researchers and widely varied academic research experience, as well as developing and already established research.

Multidisciplinary research grants help universities strengthen their faculties and curricula and allow them to experiment with new research and training concepts before instituting extensive programs. Each institution brings unique research capabilities and talents to bear on scientific and technological problems facing the space program.

Sustaining University Program Research grants encourage institutions to exercise responsibility in selecting the research program and provide an opportunity for timely support of new researchers and new ideas.

#### Administration and Management Research

This program, now entering its third year of aid to research and graduate training in the management of large, complex organizations, continued support for research programs at Syracuse University, the University of Pittsburgh, the University of Southern

California, the University of New Mexico, Northwestern University, and the National Academy of Public Administration. A new program was initiated at the Drexel Institute of Technology, and support was provided to six other universities for small research projects in management. Syracuse, Pittsburgh, and Southern California have traineeships in public administration closely integrated with their research programs, and NASA provides support for 35 trainees at these schools.

Faculty and students from these universities spent time at most NASA centers during the summer period pursuing research projects. Work underway included a study of the role and responsibilities of project managers in NASA, the design of new management information systems, a study of methods of evaluating the performance of support contractors, and an analysis of the problems involved in budgeting in research and development programs.

#### Engineering Systems Design

The engineering systems design program in graduate engineering education (*19th Semiannual Report*, p. 130) ended its second academic year in June. The first group of 23 trainees completed their course work and qualifying exams and are now working full-time on their dissertations. The second group of 25 trainees completed its first year in the program, and most have chosen their design project. Members of this group made the choice much more quickly than did those in the first group. Projects undertaken included a microwave adapter for reception from direct broadcast satellites, a lunar personal-powered pogo transporter, a laser doppler velocimeter, design criteria for thin-walled shells (Stanford); a shuttle vehicle to moonbase (Cornell); and health systems (Georgia Tech).

A third group of 25 traineeships was awarded to the 5 universities (Stanford, Purdue, Kansas, Cornell, and Georgia Institute of Technology) during this period for students to start training in September 1969.

#### Special Training

Special training activities vary from specialized four-week courses to three-year programs leading to an advanced degree and involve faculty, graduate, and undergraduate students. This category includes the Summer Faculty Fellowship program, Summer Institutes for talented undergraduates, a post-M.D. effort at Har-

vard and Ohio State Universities to provide advanced training in support of the manned space program, and a few predoctoral training grants in specific areas related to the space program.

Under the Summer Faculty Fellowship program, grants were made which will enable 12 universities and 9 field centers to cooperate by offering 10 weeks of research and study opportunities to about 280 faculty members. In 1969, under the Summer Faculty Fellowship program in engineering systems design, about 80 faculty members will participate in programs conducted by Stanford University in cooperation with the Ames Research Center; the University of Houston in cooperation with Rice University and the Manned Spacecraft Center; the Old Dominion University in cooperation with the Langley Research Center; and Auburn University in cooperation with the University of Alabama and the Marshall Space Flight Center.

NASA also sponsored summer institutes for outstanding undergraduates at Columbia University, University of California at Los Angeles, the University of California, Santa Barbara, and the State University of New York at Stony Brook. About 100 senior undergraduates will receive six weeks of specialized summer training in space science and technology. Advanced training in aerospace medicine was continued for a few selected physicians at Harvard University and Ohio State University.

Five predoctoral training grants were made to support the training of 25 new predoctoral students in specific areas related to the national space program—in aeronautics and lasers and optics at Stanford University, vibrations and noise at North Carolina State University and the Pennsylvania State University, and international studies in space science and technology at the University of Miami.

One hundred thirty-nine universities (already participating in the NASA Predoctoral Training Program) were authorized to utilize unexpended stipend monies from funds obligated by NASA to the universities in the 1964 and 1965 fiscal years. The funds released will provide support for about 350 new graduate students to begin working toward a doctoral degree in space-related science and technology in September 1969. This will be the first new group entering the Predoctoral Training Program since fiscal year 1967, because no funds were available to start new students in 1968 or 1969. Since the beginning of the program, about 1,700 students have received doctoral degrees.

## Resident Research Associateship Program

In this program, administered by the National Research Council, National Academy of Sciences, National Academy of Engineering, 159 postdoctoral and senior-postdoctoral investigators conducted advanced research at NASA field centers. They were distributed among NASA centers as follows:

<i>Center</i>	<i>Participants</i>
Goddard Space Flight Center -----	64
Greenbelt, Maryland -----	41
Institute for Space Studies, N.Y. -----	23
Ames Research Center -----	31
Marshall Space Flight Center -----	12
Langley Research Center -----	10
Manned Spacecraft Center -----	10
Jet Propulsion Laboratory -----	24
Electronics Research Center -----	8
Total -----	159

## Research Facilities

Additional structures at Case Institute of Technology, and Western Reserve, Rochester, Stanford, and Wisconsin Universities were completed and occupied by researchers, bringing to 34 the number of completed buildings. These structures now provide over 1½ million square feet of space on university campuses and can accommodate some 3,800 university scientists, engineers, and others engaged in aerospace science and technology research.

Table 8-1 summarizes the status of the three remaining active grants.

TABLE 8-1. Research facilities in process, June 30, 1969

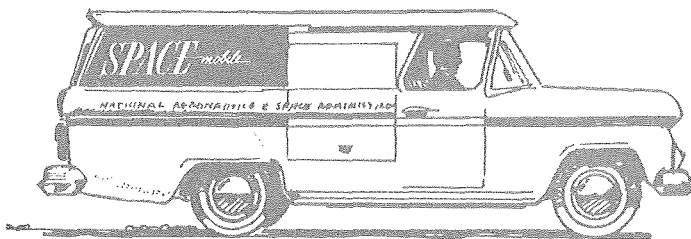
Fiscal Year awarded	Institution	Topic	Area (1,000 SF)	Percent complete	Cost (\$1,000)
1966 -----	Washington -----	Aerospace Research -----	40	90	\$1,500
	Kansas -----	Space Technology -----	56	20	1,800
			96	-----	3,300
1968 -----	National Academy of Science.	Lunar Science Institute ---	17	95	668
Total -----			113	-----	\$8,968

## RESEARCH GRANTS AND CONTRACTS

The Office of University Affairs, which continued to handle all university and unsolicited proposals submitted to Headquarters, received 1,584 proposals of which 395 were rejected and 976 were funded.

Approximately 1,100 project-oriented university grants and 500 contracts are in effect. The use of step funding (*20th Semiannual Report*, p. 166) to insure stability of research at universities was further expanded. Past efforts were approximately doubled as \$10 million was applied to 160 additional grants. NASA now has nearly one-third of its active project grants on a stable funding basis.

# 9 INFORMATIONAL AND EDUCATIONAL PROGRAMS



Students, teachers, educators, scientists, engineers, businessmen, industrialists, and many others were becoming increasingly aware of the present and possible future benefits of the space age through NASA's informational and educational programs. A brief account of some current activities in these diversified programs follows.

## EDUCATIONAL PROGRAMS And SERVICES

Explaining manned space flight missions to 69,000 disadvantaged children in 51 cities, NASA carried out the Vice President's Summer Space Education Program in cooperation with the President's Council on Youth Opportunity. To further serve the educational needs of young people, the Agency recognized 236 high school science students for outstanding research projects in its Youth Science Congress program conducted in cooperation with the National Science Teachers Association. The students reported on their projects to fellow students and to scientists throughout the country.

NASA's services to teachers in summer workshops included providing audiovisual materials, publications, exhibits, field trips, consultants, and speakers. Over 2,000 teachers in 29 states were assisted through 46 programs during June (*20th Semiannual Report*, p. 167.)

### Spacemobiles

In addition, NASA space science lecture-demonstration units (spacemobiles) made over 8,500 presentations before school children, and educational and civic groups. Besides this audience of more than 2 million, an estimated 27 million were reached through 43 radio and television programs. Also, traveling lecture-demonstration units—manned by local lecturers trained by NASA specialists—operated in Brazil, Israel, and Yugoslavia.

### Educational Publications and Films

The Agency released a number of new educational publications and new motion pictures which are described in appendix M.

### Educational TV and Radio

Half-hour film documentaries on the Apollo 8, 9, and 10 flights were produced and distributed to about 600 requesting stations within three weeks after the completion of each mission. The films were made available for public service programming on commercial and noncommercial stations and for screenings in schools and other institutions. In June, two additional special TV programs were made in advance of the Apollo 11 lunar landing mission—a half-hour summary of space efforts and a 15-minute advance report on this flight.

Special short films also were produced and made available to television stations before each Apollo flight. They provided short background stories on various facets of the missions. Thirty of them were films in the *Apollo Digest* series, completed earlier but re-released as timely stories for newscasts or other uses.

The monthly five-to-15-minute *Aeronautics and Space Report* continued to receive wide acceptance. The program—with coverage ranging from Project Apollo to aeronautical research and interplanetary travel—was telecast by 765 stations requesting it.

NASA also served educational television stations, television networks, and producers of television programs in various ways by providing information and guidance, and (if possible) assistance in locating materials to be included in the programs.

*Space Story*, a weekly five minute-taped program, was distributed to radio stations throughout the country. The monthly 15 minute *NASA Special Reports* program was sent to radio stations from coast to coast as well. Taped interviews with astronauts and project officials at the Agency's field installations and one minute-taped informational announcements, *NASA Space Notes*, were also widely distributed to radio stations periodically.

## SCIENTIFIC And TECHNICAL INFORMATION

NASA continued to improve and expand its scientific and technical information program, issuing Special Publications, instituting a bibliography service for conferences, and making its documents more readily available to the public.

### Special Publications

Some Special Publications (SP) are listed in appendix N. Three are particularly noteworthy. *The Book of Mars* (SP-179) won the Federal Editors Association's Blue Pencil Award for the best technical publication of over 50 pages. *Exploring Space With A Camera* (SP-168, 20th Semiannual Report) went into a third printing after selling a record 50,000 copies. The large sale prompted a substantial increase in the first printing order for a similar book *Earth Photographs from Gemini VI through XII* (SP-171).

### Bibliography Service for Conferences

During this period NASA initiated a new bibliography service. The Agency will prepare bibliographies on subjects to be discussed at conferences and have them ready for those attending as soon as they arrive. Under the program bibliographies compiled by NASA and edited by subject matter specialists from the American Institute of Aeronautics and Astronautics (AIAA) were made available at AIAA-sponsored conferences in February and in April.

For the February conference, a VTOL Research, Design, and Operation Meeting held in Atlanta, Ga., the bibliographies were on *Helicopter Rotor Lift Augmentation* and *Jets In Cross Winds*; for the April meeting, a Structural Dynamics and Aeroelasticity Specialists Conference at New Orleans, La., the bibliographies covered *Wave Propagation In Liquid-Filled Flexible Feedlines* and *Dynamics of Non-Homogeneous Materials*.

### Improved Availability of NASA Documents

To maximize public access to documents in NASA's scientific and technical information system, the Agency arranged for all unclassified, unlimited NASA (and NASA-sponsored) scientific and technical reports to be automatically provided the Clearinghouse for Federal Scientific and Technical Information. The Clearinghouse receives the reports directly from the printer or by daily courier from the NASA Scientific and Technical Information Facility. In addition, steps are being taken to state even more explic-

itly when items announced in NASA's abstract journal *Scientific and Technical Aerospace Reports (STAR)* are available to the public.

## TECHNOLOGY UTILIZATION

NASA strengthened its management of and control over contractors by evaluating aerospace-generated technology reported by research and development contractors and in-house laboratories; preparing and distributing special publications on technological advances of wide commercial interest; and applying new technology to identify and possibly solve public problems.

The growing number of fee-paying industrial clients of the NASA-sponsored Regional Dissemination Centers attested to the value of these institutions as an effective means of channeling new technical knowledge to business users. Other experimental Technology Utilization Programs, such as the Computer Software Management and Information Center (COSMIC) and the Biomedical Application Teams, continued to report on and transfer the latest aerospace-developed techniques for non-aerospace applications.

### Interagency Activities

NASA and the Atomic Energy Commission expanded their joint program to identify, document, and report new technology through NASA-AEC *Tech Briefs* and by such publications as Technology Utilization Handbooks and Surveys. Also, the Department of Defense and NASA began to make computer programs and documents available to industry and the public through the Computer Software Management and Information Center (p. 170).

In addition, NASA continued to cooperate with the Small Business Administration and the Office of State Technical Services to inform industry of aerospace-generated technology potentially valuable for commercial or industrial applications, and worked with the Federal Water Pollution Control Administration and the Bureau of Reclamation (both of the Department of Interior) to apply this technology to help solve problems of water pollution and weather modification. NASA also agreed to assist the new Law Enforcement Assistance Administration of the Department of Justice in solving certain law enforcement problems by using aerospace technology.

The Agency entered into agreements with the National Air Pollution Control Administration, Department of Health, Education, and Welfare, and the Department of Transportation to apply aero-

space technology toward the solution of air pollution and automotive safety problems.

#### Technology and Biomedical Applications Teams

Technology Applications Teams were being established at the Illinois Institute of Technology Research Institute and Stanford Research Institute to apply aerospace-generated technology to solving problems in mine safety, law enforcement, air pollution, and transportation. These teams will use methods similar to those of the Biomedical Application Teams.

The three NASA-sponsored Biomedical Application Teams have worked closely with about 150 biomedical researchers and clinicians to pinpoint problems which could be solved through the application of aerospace technology. Further, the teams were making a special effort to find out if sensory aids developed in aerospace research might help the deaf and the blind.

#### Identifying and Reporting New Technology

Even though over 14,000 technology items developed by NASA and its contractors have been identified and reported through the Technology Utilization Program, steps were taken early in 1968 to improve this reporting system. A NASA handbook of guidelines to document the new technology was issued and distributed to the Agency's field centers and their contractors, and standardized new technology report forms were made available to facilitate evaluation and publication.

New technology identification and reporting were receiving greater emphasis as NASA undertook the research and development projects of the Viking and the Apollo Applications Programs (ch. 2), and the reporting was increasingly directed toward *prospective* identification of new technology rather than the retrospective methods being used. The forward-looking emphasis should step up the Agency's transfer of aerospace technology for non-aerospace uses.

#### Project COSMIC

About 16,000 orders for computer software were filled for businessmen, industrialists, and educators. The material came from the 500 computer programs and associated documentation contained in the inventory of the Computer Software Management and Information Center (COSMIC) at the University of Georgia. However, to further public awareness of this valuable resource, the availability of this software will be made known on a more comprehensive

basis through the NASA-sponsored Regional Dissemination Centers. In addition, the Agency will publish a Computer Program Abstract Journal listing these programs, which will be sold by the Government Printing Office.

#### Regional Dissemination Centers

The six Regional Dissemination Centers, located at universities or non-profit research institutions, were serving over 500 companies—about one-third of them small business clients. These NASA-sponsored experimental Centers provide information packages of aerospace technology which may be applied to solving the technical and managerial problems of industry.

#### Program Evaluation

The Denver Research Institute was analyzing certain aspects of the identification, publication, and dissemination processes of the Technology Utilization Program. In its first year of studies, the Project for the Analysis of Technology Transfer completed an analysis of the characteristics of requestors of detailed technical information packages, and developed a data bank documenting several thousand cases of technology transfer.

### HISTORICAL PROGRAM

NASA published a chronology of aeronautical and astronautical events for 1967 (appendix N) and a *History of Aeronautics and Astronautics: A Preliminary Bibliography* (HHR-29) during the first six months of this year. Project Gemini and Project Apollo chronologies were in press. Drafts of histories of Project Gemini, of the Apollo launch facilities at Kennedy Space Center, and of monographs on the Manned Space Flight Network and sounding rockets were circulated for comment.

To complete the NASA contribution to the Departmental Histories Project (*20th Semiannual Report*, p. 172), a supplement was prepared to cover the period of service of Dr. T. O. Paine as Acting Administrator under the Johnson Administration. This document will be deposited in the Lyndon B. Johnson Presidential Library.



## SUPPORTING ACTIVITIES

The numerous functions providing the essential support for the operating programs received continuing emphasis during the period. NASA gave meaningful stress to personnel training; individuals and groups were recognized and rewarded for contributions to the space program; management improvements were achieved; actions were taken to achieve greater economy and efficiency in all aspects of procurement and supply management; Agency cooperation with other government agencies led to better working relationships; and the NASA Safety Program made headway in its efforts to prevent or preclude risk incidents.

### PERSONNEL

Personnel activities emphasized included employee-management relations, training, and the equal employment opportunity program. Ten key personnel changes occurred, and numerous individuals and groups were recognized for significant achievements or contributions to the space program.

#### Employee-Management Cooperation

NASA continued to participate in the government-wide program for Employee-Management Cooperation in the Federal service (Executive Order 10988). The collective bargaining agreement between the George C. Marshall Space Flight Center and Local 1858, National Federation of Government Employees, was approved by Headquarters. This agreement was the second to be negotiated at the Center, and it is to remain in force and effect for three years.

An alleged unfair labor practice charge filed by Lodge 892, International Association of Machinists and Aerospace Workers

(AFL-CIO), against the Langley Research Center was resolved informally at the local level. Local 2182 of the American Federation of Government Employees requested the Director, Lewis Research Center, to grant exclusive recognition for a unit of 20 firemen. The request was denied and subsequently appealed by the National President of the AFGE. At period's end, Headquarters was considering the merits of the request from the Director, LeRC, for arbitration. The Kennedy Space Center began to negotiate its first agreement between the Center and Local 2498, American Federation of Government Employees.

Under the new Coordinated Federal Wage System, NASA and the American Federation of Government Employees union jointly participated in a full-scale wage survey of the Cleveland, Ohio, area. Management and union representatives worked together as members of the Cleveland Local Wage Survey Committee. In addition, the data collection teams were composed of one management and one union representative. At the NASA Headquarters level, management and union representatives served as members of the Agency Wage Committee. The new wage schedule resulting from this survey applies to all Federal agencies in the Cleveland, Ohio, area having wage board employees.

#### Training Activities

NASA continued to place heavy emphasis on supervisory development. It issued supplements to new Federal Personnel Manual sections on Supervisory Training and on Promotion and Internal Placement to provide criteria and guidelines to Headquarters and Centers in implementing supervisory training and merit promotion plan requirements.

The Agency's own course, "Supervision and Management in NASA," a 40-hour program of instruction in the concepts and practices of NASA supervision and personnel management, continued to be tested; presentations of the approved version began in June 1969 and will be continued throughout the Agency. This course and related activities stimulated a reevaluation of all supervisory training efforts, resulting in updating in-house courses and wider use of Civil Service Commission programs.

NASA conducts specialized seminars on an agency-wide basis to provide training for program and project teams and to promote management improvement and uniform treatment of NASA policy. During this period, courses in Procurement Management, Contract Administration, Contractor Performance Evaluation,

Written Communications for Executives, and Contract Cost Management were conducted for NASA employees. Two new courses—Effective Use of Reliability Program Outputs in Project Decisions and Assuring Effectiveness of Contractor Reliability Assurance Programs—were also conducted.

Ten NASA executives attended the Federal Executive Institute, and sixteen executives were selected to attend it during the coming year.

Eight NASA employees were selected to attend long term fellowship programs such as the MIT-Sloan, the Stanford Sloan, the National Institute of Public Affairs (Educational Program in Systematic Analysis), the Industrial College of the Armed Forces, the Princeton Mid-Career, and the Hugh L. Dryden Memorial Fellowship.

NASA installations continued their recurring programs such as academic education, cooperative education, apprentice training, science and engineering lecture programs, and a wide variety of management and skills training.

Two film strips with tape narrations on position management and position classification were produced by Personnel Division. The programs depicted actual operations within the Agency to provide managers, supervisors, and employees with basic information on these two topics.

The films proved to be particularly effective in informing a comparatively young work force new to federal service about two programs being given emphasis not only within NASA but within other federal agencies. The films were directed toward helping managers and supervisors improve their use of position management and position classification program elements as a part of their overall personnel management responsibilities. NASA audiences reacted favorably to the films. Subsequently, the Civil Service Commission, the Department of Transportation, the Air Force, and the Navy requested prints of the films.

#### Equal Employment Opportunity

The Civil Service Commission recently revised the Equal Employment Opportunity Regulations to provide a new system for processing complaints of discrimination on grounds of race, color, religion, sex, or national origin. The new regulations are effective July 1, 1969. To help implement these regulations, NASA formed an advisory Committee on EEO to advise and assist the EEO officer in establishing action items, goals, and objectives.

### Key Executive Personnel Changes

*Appointments.*—On February 28, Dr. Hans M. Mark was appointed Director of the NASA Ames Research Center. Dr. Mark came from the University of California, Berkeley, where he had been Professor of Nuclear Engineering, Director of the Berkeley Research Reactor (program), and Head, Experimental Physics Division of the Lawrence Radiation Laboratory, Livermore. From 1964 he had also been Chairman of the Department of Nuclear Engineering of the University.

Dr. Thomas O. Paine was appointed as NASA Administrator on April 3. He had served as Deputy Administrator from March 25, 1968, and as Acting Administrator from October 8, 1968.

*Reassignments.*—On January 12, William C. Schneider was appointed Director, Apollo Applications Program, within the Office of Manned Space Flight. Prior to this appointment, he had served in the dual capacity of Apollo Mission Director and Deputy Director for Missions, Apollo Program, from January 14, 1968; as Deputy Director of Mission Operations from October 1965 to January 1968; and as Deputy Director, Gemini Program from November 1, 1963, to October 1965. He joined NASA June 24, 1963.

Clarence A. Syvertson was appointed Deputy Director of the NASA Ames Research Center on February 28, succeeding John F. Parsons. Mr. Syvertson had been Assistant Center Director for Astronautics from September 1, 1966; Director of the (Headquarters) Mission Analysis Division, Office of Advanced Research and Technology (located within the Ames Center) from December 13, 1965, to September 1966; and Chief, Mission Analysis Division at the Ames Center from March 1963 to December 1965.

On June 15, Leonard Jaffe was appointed Deputy Associate Administrator for Space Science and Applications (for Applications). From January 24, 1966, he had been Director of Space Applications Programs and, from January 1959 to January 1966, Director of Communications and Navigation (Satellite) Programs.

*Terminations.*—On January 31, Dr. Arthur L. H. Rudolph retired from the position of Manager, Saturn V Program, at the NASA George C. Marshall Space Flight Center. He had served in this capacity from August 1963, and had transferred to the Center from the Army Ballistic Missile Agency (ABMA) in January 1962. Earlier, he had been Project Director for the ABMA developments of the Redstone and Pershing missile systems. From July 1960 to December 1961, he served as Director of Research and Development for ABMA.

On February 28, Harry Julian Allen retired from the position of Special Assistant to the Associate Administrator for Advanced Research and Technology. (While in this position he had also been Acting Director, NASA Ames Research Center.) Mr. Allen had been Director of the Ames Research Center from October 16, 1965 to November 15, 1968; he had planned to retire in November, 1968, but stayed on during the time required to search for and select a successor.

Harold B. Finger resigned (on April 26) from the position of Associate Administrator for Organization and Management to become Assistant Secretary of Housing and Urban Development for Research and Technology. For twenty-five years Mr. Finger had been a research scientist and manager at the Lewis Research Center. Between October 1958, and March 1967, he had headed the nuclear systems research and development efforts of NASA (serving additionally as Manager of the joint NASA/AEC Space Nuclear Propulsion Project from August 1960).

Philip N. Whittaker resigned from the position of Assistant Administrator for Industry Affairs on May 6. Mr. Whittaker came to NASA from the International Business Machines Corporation, where he served as Vice President of IBM's Federal Systems Division.

On May 10, Richard L. Leshner resigned from the position of Assistant Administrator for Technology Utilization. Mr. Leshner joined NASA in May 1965, as Deputy Assistant Administrator for Technology Utilization.

#### NASA Awards and Honors

Twenty-three people were awarded the NASA Distinguished Service Medal during this period.

*Frank Borman, MSC.*—For outstanding contribution to space flight, engineering, and exploration as Commander of Apollo 8, December 21 to December 27, 1968.

*William A. Anders, MSC.*—For outstanding contributions to space flight, engineering, and exploration as Lunar Module Pilot of Apollo, December 21 to December 27, 1968.

*James A. Lovell, Jr., MSC.*—For outstanding contributions to space flight, engineering, and exploration as Command Module Pilot of Apollo 8, December 21 to December 27, 1968.

As a part of the Special Apollo 8 Awards, the following were also presented the Distinguished Service Medal in recognition of their outstanding leadership and exceptional contributions and for their managerial skill, dedication, and personal efforts contributing to

the success of Apollo 8: Kurt H. Debus, KSC; Robert R. Gilruth, MSC; Christopher C. Kraft, Jr., MSC; George M. Low, MSC; George E. Mueller, Hdqs.; Rocco A. Petrone, KSC; Lt. Gen. Samuel C. Phillips, Hdqs.; Eberhard F. M. Rees, MSFC; Arthur Rudolph, MSFC; William C. Schneider, Hdqs.; Gerald M. Truszynski, Hdqs.; and Wernher von Braun, MSFC.

*James A. McDivitt, MSC.*—For his outstanding contributions to the Nation's manned space flight program and the advancement of space technology as commander of Apollo 9.

*David R. Scott, MSC.*—For his outstanding contributions to the nation's manned space flight program and the advancement of space technology as command module pilot of Apollo 9.

*Russell L. Schweickart, MSC.*—For his outstanding contributions to the Nation's manned space flight program and the advancement of space technology as lunar module pilot of Apollo 9.

*Jesse L. Mitchell, Hdqs.*—For his outstanding service as Director of NASA's Physics and Astronomy Programs in organizing university, industry, and government teams.

*Joseph Purcell, GSFC.*—For his outstanding leadership and technical contributions as Project Manager of the Orbiting Astronomical Observatory.

*Thomas P. Stafford, MSC.*—For his outstanding performance as Commander of the Apollo 10 flight, the first lunar orbital qualification test of a complete Apollo spacecraft.

*John W. Young, MSC.*—For his outstanding performance as Command Module Pilot of Apollo 10.

*Eugene A. Cernan, MSC.*—For his outstanding performance as Lunar Module Pilot of the Apollo 10 flight.

*Frederick Seitz, National Academy of Science.*—Received the Distinguished Public Service Medal for his distinguished service to the nation in advancing cooperation between the scientific community and government as the first fulltime President of the National Academy of Science.

Sixty-nine Exceptional Service Medals were awarded as follows: Donald D. Arabian, MSC; C. Dixon Ashworth, Hdqs.; Rear Adm. Fred E. Bakutis, Task Force 130, DOD; Col. Oakley W. Baron, A/RIA Commander, DOD; Carrol H. Bolender, MSC; William D. Brown, MSFC; Clifford E. Charlesworth, MSC; John F. Clark, GSFC; Raymond L. Clark, KSC; Aaron Cohen, MSC; Ozro Covington, GSFC; Leroy E. Day, Hdqs.; Paul C. Donnelly, KSC; Friedrich Duerr, MSFC; Lynwood C. Dunseith, MSC; Maxime A. Faget, MSC; Robert F. Garbarini, Hdqs.; Robert A. Gardiner,

MSC; Ernst D. Geissier, MSFC; Roy E. Godfrey, MSFC; Erich E. Goerner, MSFC; Robert E. Gorman, KSC; Wilbur H. Gray, MSC; Hans P. Gruene, KSC; Walter Haeussermann, MSFC; George H. Hage, Hdqs.; Jerome B. Hammack, MSC; Karl L. Heimbürg, MSFC; Maj. Gen. Vincent G. Huston, DOD; Lee B. James, MSFC; Richard S. Johnston, MSC; Maj. Gen. David M. Jones, DOD; Kenneth S. Kleinknecht, MSC; Joseph N. Kotanchik, MSC; Eugene F. Kranz, MSC; Donald A. Krueger, GSFC; Chester M. Lee, Hdqs.; William R. Lucas, MSFC; H. Robert Lynn, GSFC; Edward R. Mathews, KSC; John P. Mayer, MSC; Owen E. Maynard, MSC; James C. McCulloch, MSFC; Roderick O. Middleton, KSC; William A. Mrazek, MSFC; Warren J. North, MSC; Maj. Gen. Edmund F. O'Connor, MSFC; George F. Page, KSC; G. Merritt Preston, KSC; Ludie G. Richard, MSFC; Tecwyn Roberts, GSFC; Jack Sargent, GSFC; Ralph S. Sawyer, MSC; Julian Scheer, Hdqs.; Karl Sandler, KSC; Scott H. Simpkinson, MSC; Sigurd A. Sjoberg, MSC; Donald K. Slayton, MSC; Fridtjof A. Speer, MSFC; Laverne R. Stelter, GSFC; Joseph G. Thibodaux, Jr., MSC; Henry F. Thompson, GSFC; Howard W. Tindall, MSC; Matthew W. Urlaub, MSFC; William P. Varson, GSFC; Eugene W. Wasielewski, GSFC; Herman K. Weidner, MSFC; John J. Williams, KSC; and H. William Wood, GSFC.

Exceptional Scientific Achievement Medals were presented to James E. Kupperian, GSFC, and Nancy G. Roman, Hdqs.

The NASA Public Service Award was presented to Charles R. Able, McDonnell Douglas Corp.; William M. Allen, Boeing Co.; John L. Atwood, North American Rockwell Corp.; William B. Bergen, North American Rockwell Corp.; B. Paul Blasingame, A C Electronics Division of GMC; Arthur D. Code, Washburn Observatory; Richard D. DeLauer, TRW Systems Group, TRW Inc.; C. Stark Draper, Massachusetts Institute of Technology; Bob O. Evans, International Business Machines Corp.; Llewellyn J. Evans, Grumman Aircraft Engineering Corp.; L. F. Graffis, Bendix Field Engineering Corp.; William P. Gwinn, United Aircraft Corp.; Samuel K. Hoffman, North American Rockwell Corp.; Robert E. Hunter, Philco-Ford Corp., Howard W. Johnson, Massachusetts Institute of Technology; T. Vincent Learson, International Business Machines Corp.; James S. McDonnell, McDonnell Douglas Corp.; Kenneth G. McKay, American Telephone & Telegraph Co.; Reginald I. McKenzie, Aerojet-General Corp.; Donald L. Moyer, Grumman Aircraft Engineering Corp.; Hilliard W. Paige, General Electric Co.; Ian M. Ross, Bellcomm, Inc.; Robert W. Schaeffer, Bendix Field Engineering Corp.; Nicholas S. Sinder, Grumman

Aircraft Engineering Corp.; Lyman Spitzer, Princeton University Observatory; George H. Stoner, Boeing Co.; Harold Wexler, Grumman Aircraft Engineering Corp.; Fred L. Whipple, Smithsonian Astrophysical Observatory; and Robert B. Young, Aerojet-General Corp.

Group Achievement Awards were presented to Apollo 8 Communication Network, USS Yorktown (CVS-10) and Embarked Air Group, Manned Space Flight Network, Office of Public Affairs, OAO-II Project Team (Project Management and Support), OAO-II Project Team (Launch Vehicle Management), OAO-II Project Team (Launch Operations Support), Color Television Development Team, and Lunar Potential Analysis Group,

The NASA Certificate of Appreciation was awarded to John S. Patton and Frank J. Magliato of NASA Headquarters. It was also awarded to the members of the University-NASA Science and Technology Advisory Committee: Luis Alvarez, H. Stanley Bennett, Francis H. Clauser, Lee DuBridge, Leo Goldberg, Harry Hess, T. William Lambe, Gordon J. F. MacDonald, William G. Shepherd, William Shockley, William Sweet, Charles Townes, John Whinnery, and George D. Zuidema.

#### Status of Personnel Force

These figures represent total employment (including temporaries) for the periods ending as indicated.

	<i>December 31, 1968</i>	<i>June 30, 1969</i>
Headquarters NASA -----	2,213	2,293
Ames Research Center -----	2,050	2,117
Lewis Research Center -----	4,397	4,399
Langley Research Center -----	4,024	4,087
Flight Research Center -----	574	601
Electronics Research Center -----	844	951
Space Nuclear Propulsion Office -----	105	104
Goddard Space Flight Center -----	3,800	4,295
Wallops Station -----	504	554
NASA Pasadena Office -----	72	80
Marshall Space Flight Center -----	6,505	6,639
Manned Spacecraft Center -----	4,629	4,751
Kennedy Space Center -----	2,966	3,058
Total -----	<u>32,683</u>	<u>33,928</u>

#### INVENTIONS And CONTRIBUTIONS BOARD

The Administrator of NASA redesignated the membership and Director of the Staff of the Inventions and Contributions Board. One change was made in the membership. Mr. Clarence R. Morri-

son, OART, was designated to succeed Mr. Robert E. Littell, also of OART, who resigned after more than ten years of service as a Board member. A listing of the present Board membership appears in appendix F.

The Inventions and Contributions Board has three principal functions. First, it reviews petitions for waiver of patent rights that have been submitted by NASA contractors, recommends the disposition of each petition, and sends its recommendations to the Administrator for final decision. Second, it considers and evaluates the merits of inventions and other scientific and technical contributions reported by in-house and contractor employees. Subsequently, it recommends to the Administrator that monetary awards be granted for qualified inventions and contributions, specifying an equitable amount. In addition, the Board is authorized to grant monetary awards of up to \$5000 (Government Employees' Incentive Awards Act of 1954) for inventions made by Government employees. Third, the Board also considers applications for awards for scientific and technical contributions received from members of the general public, both foreign and domestic.

#### Board Actions on Petitions for Patent Waiver

The staff of the Board analyzed, evaluated, and presented to the Board 56 petitions for waiver of patent rights to individual inventions. The Board's findings and recommendations were sent to the Administrator, who granted 53 petitions and denied 3 (petitioners and decisions are listed in appendix G). Fourteen petitions for blanket waiver of patent rights to all inventions made during contract performance were also considered by the Board. Of these, the Administrator granted ten and denied four (petitioners and decisions are listed in appendix H). In addition, the Administrator granted 18 petitions for patent waiver which had been recommended by the Advance Waiver Review Panel of the Board prior to placement of contracts (petitioners and decisions are listed in appendix H). The panel also considered three other petitions for waiver which were not granted. Altogether, the Board and the Administrator acted on 88 petitions for waiver.

#### Summary on Commercialization of Waived Inventions

In May, the staff of the Board prepared its second edition of "A Summary of Reports on Commercialization Activities of Patent Waiver Grantees." The first report which was issued in April, 1968, indicated commercialization of 37 inventions. The second report indicated that an additional 22 waived inventions have been

commercialized and that a substantial number of additional inventions were in the process of being commercialized.

#### Publication of Patent Waiver Recommendations

Under the supervision of the Board's staff, a new supplement to the publication, "Petitions For Patent Waivers—Findings of Fact and Recommendations of NASA's Inventions and Contributions Board," was compiled and published. The new supplement, identified as NHB 5500.1A-Change 5, was published in June 1969, and may be purchased from the Superintendent of Documents.

#### Monetary Awards for Inventions and Contributions

The Board recommended and the Administrator granted awards in three categories during this period. First, a total of 56 minimum invention awards were recommended and resulted in granting \$50 payments to 80 individuals for developing and reporting inventions upon which U.S. patent applications were subsequently filed. Second, 40 monetary awards, exceeding \$50, were made to 61 individuals for inventions and other scientific and technical contributions judged to be of significant value to an aeronautical or space program. Appendix I includes the title of each contribution for which a minimum award was granted (marked by an asterisk), as well as the title of each contribution which was granted an award in excess of the minimum.

Third, 429 Tech Brief Awards were made involving the payment of \$25 to each of 721 individuals who participated in developing and reporting innovations and new technology which were subsequently published as NASA Tech Briefs.

#### Incentive Act Awards

The Board granted monetary awards to 64 employees of NASA and other U.S. Government agencies who participated in making 42 inventions related to space and aeronautical activities. The total amount of money granted for Incentive Act Awards for this reporting period was \$10,400. A listing of these awards, which identifies the invention, the inventor, and the NASA Research Center, appears in appendix J.

#### Other Board Activities

On May 20–21, the Board convened its first conference at Headquarters on the subject of the NASA Monetary Awards Program for Scientific and Technical Contributions. Attending were Patent Counsels and Awards Liaison Officers from all NASA Field Installations. Headquarters was represented by the members of

the Board and its staff as well as by representatives from the Office of the Patent Counsel, from the Technology Utilization Division, and from the Office of Industry Affairs. The meeting emphasized procedures for implementing new awards programs. Attendees studied the design and use of a revised Awards Evaluation Questionnaire for technical evaluation of scientific and technical contributions, and considered specific award cases of a complex nature.

## FINANCIAL MANAGEMENT

On June 20, the Comptroller General of the United States approved NASA's principles and standards of accounting and the design of the accounting system. Action will continue to be taken to make certain that these principles are properly implemented.

### Budget Formulation

To help formulate its budget, NASA expanded the use of Automatic Data Processing (ADP) procedures in preparing and consolidating agency estimates. Selected special analyses which were previously prepared manually (geographical distribution of the NASA budget, for instance) were mechanized. Such mechanization made the data more readily available for use in responding to inquiries from the Congress, the White House, the Bureau of the Budget, and planning organizations outside of Government.

Magnetic-tape typewriter equipment was used successfully on an experimental basis in preparing the 1970 budget justification material. This avoided any major retyping effort. It also precluded use of less desirable shortcut methods for handling revisions. Automatic printout of selected material eliminates or reduces the necessity for retyping and reproofing material not affected by a change. The equipment also permits storage on tape and printout of material used in more than one volume of the justification.

### Agency-wide Reporting Improvements

After an Agency-wide survey of reporting requirements, NASA eliminated one manual, one Financial Status of Programs (FSP), one Object Class, and two Status of Contracts and Grants (SCAG) reports. Also, the Agency reduced the number of required copies of four other mechanized reports. These efforts resulted in an annual reduction of some 250,000 pages of reports. Further reductions are being planned.

In another area of effort, NASA cancelled a quarterly report previously required of approximately 1,200 universities and non-

profit institutions. In the future, this information will be specifically requested under particular grants and contracts as needed.

A revision was drafted of the NASA handbook, Procedures for Reporting Cost Information from Contractors. The draft includes recommended improvements which would correlate cost and schedule information. Also, because of the need for a cohesive system of contractor cost and schedule reporting, the Agency developed a Financial and Cost/Schedule Performance Measurement Annex for the Statement of Work Handbook. The Annex emphasized the requirement for the cost schedule aspects of the Work Breakdown Structure to be correlated during the planning stage, thus helping management to evaluate the contractor's performance.

#### Fiscal Year 1970 Program

Table 10-1 shows the level of effort in research and development, construction of facilities, and research and program management for fiscal year 1970, as authorized by the National Aeronautics and Space Administration Authorization Act of 1970.

TABLE 10-1—NASA Appropriation Authorizations  
Fiscal Year 1970

(In thousands)

Research and development:	
Apollo .....	\$1,691,100
Space flight operations .....	225,627
Advanced missions .....	2,500
Physics and astronomy .....	117,600
Lunar and planetary exploration .....	138,800
Bioscience .....	20,400
Space applications .....	128,400
Launch vehicle procurement .....	112,600
Sustaining university program .....	9,000
Space vehicle systems .....	27,500
Electronics systems .....	33,550
Human factor systems .....	22,100
Basic research .....	20,250
Space power and electric propulsion systems .....	36,950
Nuclear rockets .....	50,000
Chemical propulsion .....	22,850
Aeronautical vehicles .....	77,700
Tracking and data acquisition .....	278,000
Technology utilization .....	5,000
Total, research and development .....	3,019,927
Construction of facilities .....	58,200
Research and program management .....	637,400
Total .....	<u>\$3,715,527</u>

## Financial Reports, June 30, 1969

Table 10-2 shows fund obligations and accrued costs incurred during the six months ended June 30, 1969. Appended to the table is a summary by appropriation showing current availability, obligations against this availability, and unobligated balances as of June 30, 1969.

TABLE 10-2—Status of Appropriations as of June 30, 1969

(In thousands)

Six Months Ended June 30, 1969			
Appropriations	Obligations	Accrued Costs	
Research and development:			
Apollo -----	\$769,283	\$1,062,906	
Apollo applications -----	193,614	92,208	
Advanced missions -----	3,914	4,209	
Completed missions -----	(14)	(18)	
Physics and astronomy -----	58,790	68,237	
Lunar and planetary exploration -----	45,538	53,778	
Bioscience -----	18,761	19,780	
Space applications -----	45,701	52,519	
Launch vehicle procurement -----	51,463	64,564	
Sustaining university program -----	8,787	11,860	
Space vehicle systems -----	20,096	20,031	
Electronics systems -----	21,892	21,275	
Human factor systems -----	15,689	11,940	
Basic research -----	11,489	10,699	
Space power and electric propulsion systems --	23,230	21,653	
Nuclear rockets -----	25,872	19,561	
Chemical propulsion -----	20,799	16,584	
Aeronautical vehicles -----	27,973	32,582	
Tracking and data acquisition -----	132,372	186,089	
Technology utilization -----	2,203	2,204	
Reimbursable -----	47,478	43,445	
Total, research and development -----	1,544,930	1,816,106	
Construction of facilities -----	37,806	30,328	
Research and program management -----	326,271	327,991	
Totals -----	\$1,909,007	\$2,174,425	
<div> <div>Current</div> <div>Total</div> <div>Unobligated</div> </div>			
Appropriation Summary	Availability <sup>1</sup>	Obligations	Balance
Research and development -----	\$1,828,719	\$1,544,930	\$283,789
Construction of facilities -----	85,212	37,806	47,406
Research and program management --	326,418	326,271	147
	\$2,240,349	\$1,909,007	\$331,342

<sup>1</sup> The availability listed includes authority for anticipated reimbursable orders.

Table 10-3 shows NASA's consolidated balance sheet as of June 30, 1969, compared to that of December 31, 1968. Table 10-4 summarizes the sources and applications of NASA's resources during the six months ended June 30, 1969. Table 10-5 provides an analysis of the net change in working capital disclosed in table 10-4.

TABLE 10-3—NASA Comparative Consolidated Balance Sheet  
June 30, 1969 and December 31, 1968  
(In millions)

	<i>Assets</i>	<i>June 30, 1969</i>	<i>Dec. 31, 1968</i>
Cash:			
Funds with U.S. Treasury -----		\$1,738.9	\$3,859.6
Accounts receivable:			
Federal agencies -----		23.5	20.8
Other -----		13.2	3.4
		<u>36.7</u>	<u>24.2</u>
Inventories:			
NASA-held -----		40.5	38.7
Contractor-held -----		288.5	317.5
		<u>329.0</u>	<u>356.2</u>
Advances and prepayments:			
Federal agencies -----		14.2	10.5
Other -----		18.8	31.7
		<u>33.0</u>	<u>42.2</u>
Deferred charges -----		.3	9.0
Fixed assets:			
NASA-held -----		3,456.0	3,334.2
Contractor-held -----		822.2	709.2
Construction in progress -----		206.9	500.5
		<u>4,485.1</u>	<u>4,543.9</u>
Other assets -----		322.8	59.6
Total assets -----		<u>\$6,945.8</u>	<u>\$8,894.7</u>
	<i>Liabilities and Equity</i>		
Liabilities:			
Accounts payable:			
Federal agencies -----		\$121.5	\$124.8
Other -----		553.9	553.5
		<u>675.4</u>	<u>678.3</u>
Accrued annual leave -----		39.3	34.4
Deferred credits -----		20.1	—
Total liabilities -----		<u>734.8</u>	<u>712.7</u>
Equity:			
Net investment -----		4,453.4	4,290.4
Undisbursed allotments -----		1,710.0	3,083.4
Unapportioned and unallotted appropriation -----		150.0	923.5
		<u>6,313.4</u>	<u>8,297.3</u>
Less reimbursable disbursing authority uncollected		(102.4)	(115.3)
Total equity -----		<u>6,211.0</u>	<u>8,182.0</u>
Total liabilities and equity -----		<u>\$6,945.8</u>	<u>\$8,894.7</u>

TABLE 10-4—Resources Provided and Applied  
Six Months Ended June 30, 1969

(In millions)

<i>Resources Provided</i>			
Revenues .....		\$	51.0
Decrease in working capital (Table 10-5) .....			1,907.3
Decrease in fixed assets:			
NASA-held .....			(121.8)
Contractor-held .....			(113.0)
Construction in progress .....			293.6
Total decrease in fixed assets .....			58.8
Total resources provided .....			<u>\$2,017.1</u>
<i>Resources Applied</i>			
	<i>Total Costs Six Months Ended June 30, 1969</i>	<i>Less Costs Applied to Assets</i>	
Operating costs:			
Research and development .....	\$1,816.1	\$291.1	\$1,525.0
Construction of facilities .....	30.3	21.2	9.1
Research and program management .....	328.0	8.5	319.5
Total .....	<u>\$2,174.4</u>	<u>\$320.8</u>	
Total operating costs .....			1,853.6
Property transfers and retirements—net .....			161.9
Research and program management appropriation returned to Treasury .....			1.6
Total resources applied .....			<u>\$2,017.1</u>

TABLE 10-5—Net Change in Working Capital  
Six Months Ended June 30, 1969

(In millions)

	<i>June 30, 1969</i>	<i>Dec. 31, 1968</i>	<i>Increase or (Decrease)</i>
Current assets:			
Funds with U.S. Treasury .....	\$1,738.9	\$3,859.6	(\$2,120.7)
Accounts receivable .....	36.7	24.2	12.5
Inventories .....	329.0	356.2	(27.2)
Advances and prepayments .....	33.0	42.2	(9.2)
Deferred charges .....	.3	9.0	(8.7)
Other assets .....	322.8	59.6	263.2
Total current assets .....	<u>2,460.7</u>	<u>4,350.8</u>	<u>(1,890.1)</u>
Current liabilities:			
Accounts payable .....	675.4	678.3	(2.9)
Deferred credits .....	20.1	—	20.1
Total current liabilities .....	<u>695.5</u>	<u>678.3</u>	<u>17.2</u>
Working capital .....	<u>\$1,765.2</u>	<u>\$3,672.5</u>	
Decrease in working capital .....			<u>(\$1,907.3)</u>

## BOARD OF CONTRACT APPEALS

The NASA Board of Contract Appeals (established in 1958) adjudicates the appeals of the Agency's contractors that arise under the "Disputes" clause of NASA contracts. The Board is comprised of seven members appointed by the Administrator. (Members of the Board are listed in appendix L.)

The Board, acting under procedures published in Title 14, Code of Federal Regulations, Part 1241, has the authority to hold hearings; to order production of documents and other evidence; to take official notice of facts within general knowledge; and to decide all questions of fact and law raised by the appeal. The Board's decisions are final, subject to its own reconsideration or any judicial review which may be sought by the contractor on questions of law.

During the period of this report, one motion for reconsideration and nine new appeals were filed with the Board. The Board disposed of 11 appeals (most of which were filed before January 1, 1969). On June 30, the Board had 37 appeals pending on its docket.

## CONTRACT ADJUSTMENT BOARD

The NASA Contract Adjustment Board considers requests by NASA contractors for equitable contractual relief under Public Law 85-804, when no administrative legal remedy is available. The Board is comprised of five members appointed by the Administrator. (Members of the Board are listed in appendix K.)

The types of equitable relief which the Board may authorize include correcting mistakes or ambiguities in contracts and formalizing informal commitments. Also, the Board may authorize amendment of a contract without consideration, if the contractor would otherwise suffer a loss as a result of Government action, or if a loss would impair the productive ability of a contractor deemed essential to the national defense. (The Board's procedures are published in Title 41, Code of Federal Regulations, Part 18-17.)

During this period, the Board acted on four requests by contractors, granting the relief requested in one instance, granting it in part in another instance, and denying it in two instances. The case in which relief was granted involved a mutual mistake by the Government and the contractor in defining the conditions under which an incentive award would be paid. Partial relief (in an undetermined amount) was granted in a case wherein the Government had misconstrued a previous Board decision which granted relief to the same contractor on the basis of mutual mistakes. The

Board had one other request under consideration at the end of the reporting period.

The Board submits an annual report to Congress of all actions taken under the authority of P.L. 85-804 during the preceding calendar year.

### UN COMMITTEE On PEACEFUL USES Of OUTER SPACE

The Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space held its eighth session in Geneva, Switzerland, between June 9 and July 4. The NASA General Counsel was a member of the United States delegation. Three of the four weeks were devoted to further negotiation of the treaty on liability for damages caused by objects launched into outer space.

Considerable progress was made in resolving a variety of issues which had been outstanding for several years. However, significant differences remain among certain members of the Subcommittee on the question of whether the treaty should include provisions for binding arbitration in the event that a dispute arising under the treaty between a claimant state and a launching state cannot be resolved by diplomatic negotiations. It is hoped that this critical issue and several other issues not yet completely settled will be resolved prior to or during the General Assembly session beginning in September, 1969.

Other matters discussed during the Subcommittee session included the registration and marking of space objects, a proposal for a study of the legal rules which should govern human activity on the moon and other celestial bodies, a proposal for a study of the legal status of substances taken from the moon, and a suggestion that the Subcommittee consider the feasibility of creating an international space agency.

### COST REDUCTION PROGRAM

NASA's Internal Cost Reduction Program yielded savings of \$15,000,000 and its Contractor Cost Reduction Program reduced costs by \$210,000,000 during the year ending in June 1969. The NASA Internal Program goal of \$125 million for that year was exceeded, as were all prior goals since the inception of the Program. A preliminary goal of \$120 million was set for the year ending in June, 1970. From the Program's inception in 1963 through June 30, 1969, savings of \$2.1 billion have been validated and reported to the President. The Internal Program has accounted for \$1,012 billion, and the Contractor Program for \$1,110 billion.

The current NASA organization consists of a Cost Reduction Board, a Headquarters functional staff office, and cost reduction officers at all operating elements at Headquarters and at the Field Installations. The Cost Reduction Board, chaired by the Associate Deputy Administrator, determines the major policies and directs the Program and is responsible for the preparation of the semiannual reports to the President.

The NASA Cost Reduction Office is responsible for the agency-wide cost reduction program. In addition to supporting the Cost Reduction Board, this office provides policy and procedural guidance to the field installation cost reduction functions, reviews NASA-Internal and NASA-Contractor reports, evaluates center and contractor cost reduction programs, and provides recommendations to the Cost Reduction Board for improvement and intensification of the program.

During this period, the Headquarters staff evaluated the internal programs at Ames Research Center; Electronics Research Center; Flight Research Center; Kennedy Space Center; Manned Spacecraft Center; and the Marshall Spaceflight Center operations at Michoud, Mississippi Test Facility, and Huntsville. Likewise, NASA contractor operations at 10 corporate headquarters and 22 plants and divisions were subjected to formal evaluation and analysis. These on-site reviews continually strengthen and increase the effectiveness of the internal and contractor programs by revealing deficiencies requiring correction and disclose innovative approaches and ideas on cost reduction and management improvement which may be applied to NASA programs at other locations.

Quarterly and semiannual reviews of internal and contractor program cost reduction reports are conducted by the Headquarters Cost Reduction Office. Representatives of the major program offices, field installation cost reduction officers, and other NASA management officials, participate in these reviews which lead to final recommendations to the Cost Reduction Board on actions to be included in the semiannual cost reduction reports to the President.

Early in 1969, NASA was invited by the Bureau of the Budget to participate in a working panel initiated to increase the effectiveness of all cost reduction activities throughout the Government. The panel includes representatives from BOB, GAO, NASA, DOD, and several other large Government agencies. Meetings were held periodically (usually every two weeks) to review the guidance, implementation, operation, and results of the cost reduction and management improvement efforts of various governmental de-

partments and agencies, as well as private industries. Based on the findings of these reviews, BOB planned to issue new guidelines on the cost reduction and management improvement programs.

### PROCUREMENT AND SUPPLY MANAGEMENT

In its continuing efforts to obtain greater efficiency and economy in procurement and contract management, NASA took several important steps in the areas of pricing, competition, property management, and advance payments.

NASA revised its procurement regulations to strengthen the pricing procedures on small purchases. In the absence of price competition, a prospective contractor is now required to make a legally actionable representation as to the basis of his proposed price (catalog, market price, other). Under certain stipulated conditions, depending on the nature of the prospective contractor's response, the purchase file must be documented to support the reasonableness of the price paid. While this requirement is primarily designed for small purchases, NASA regulations also encourage the use of price representations where appropriate on fixed price transactions up to \$100,000.

NASA also issued new instructions to assure as nearly as possible full compliance with that portion of Public Law 87-653 (10 U.S.C. 2306 (f)) dealing with the permissive exemption of commercial items from the requirements of cost or pricing data. Under these new procedures, a prospective contractor will be expected to furnish, incident to his proposal, pertinent sales and other information to substantiate the validity of a commercial exemption under the provisions of the law. The same instructions also compel contracting officers to verify contractor claims and supporting data by means of an independent examination.

In another action concerning pricing, the NASA Procurement Regulation 3.801-3 was amended in March to define the responsibilities of individuals, other than the contracting officer, involved in contract pricing. The amendment sets forth the various duties of technical personnel, price analysts, contract administrators, auditors, and others who interact with the contracting officer to develop the Government's price objective before negotiation with the contractor. It also points out that the Armed Services Procurement Regulation Manual for Contract Pricing, ASMP No. 1, may be used as a guide in reviewing, analyzing, and negotiating contract prices. Reports by the various pricing team members will be retained as part of the official contract file along with significant work papers supporting the development of the pricing objective.

The Armed Services Procurement Act (10 U.S.C. 2304(g)) provides in part that, in all negotiated procurements in excess of \$2,500, ". . . written or oral discussions shall be held with all responsible offerors who submit proposals within a competitive range, price and other factors considered." To help obtain compliance, NASA issued new policies and procedures to provide improved guidance for determining which proposals should be considered within the competitive range, including the extent and content of the required "discussions."

NASA also took steps to tighten controls over the use of its equipment by contractors for commercial work, simultaneously increasing the rent charges for such use. At the same time, it raised the approval level for commercial use of government property to higher echelons of NASA management. The Agency's purpose is to encourage contractors to obtain their own equipment for work on government contracts.

Along this same line, instructions were being established to stop furnishing contractors with any government property costing less than \$1,000 except in cases of educational and nonprofit institutions. Additionally, the new policy will require contractors to express in writing their unwillingness or financial inability to provide adequate equipment or facilities.

NASA worked closely with the General Services Administration to develop regulations implementing Public Law 89-3068, governing the procurement of general purpose, commercially available, automatic data processing equipment (ADPE) and related supplies. NASA policy and operating instructions went to all Agency activities. Instructions were also published to stress the need for full and complete competition in ADPE procurements including sources on Federal Supply Schedule Contracts. NASA activities were instructed to solicit bids or proposals for ADPE from *all* qualified sources.

In another area, NASA issued regulations establishing uniform procedures for approving and handling advance payments to nonprofit and educational institutions. Since establishing these regulations, the Agency has reduced the time for the approval process to only 5 days. This enables nonprofit institutions having limited, or pledged funds only, to commence performance promptly under NASA research contracts.

The Agency published basic policy emphasizing the need for timely payments to contractors, stressing the need to eliminate delays at all steps in the reimbursement process. In addition to pointing up the need to accelerate payments of contractors' in-

voices, in general, the regulation also emphasized timely payment action on progress and advance payment vouchers. The regulation should eliminate delays and reduce the time required to make payment on NASA contracts.

DoD and NASA agreed that it was necessary to have additional guidance for the use of "off-site" rates when work is performed at locations physically removed from a contractor's primary location. The agencies jointly prepared a new paragraph for their respective procurement regulations furnishing such guidance (to be published soon). The creation and use of off-site rates will generally produce a more equitable distribution and recovery of overhead expenses.

During this period, NASA participated with DOD in reviewing the purchasing systems of 28 Defense contractors with whom this Agency does business. The joint efforts have been mutually advantageous and economical and will be continued.

#### Summary of Contract Awards

NASA's procurement for this period (the last 6 months of Fiscal Year 1969) totaled \$1,673 million, or \$257 million less than was awarded during the corresponding period of FY 1968.

Approximately 80 percent of the net dollar value was placed directly with business firms, 6 percent with educational and other nonprofit institutions, 5 percent with the California Institute of Technology for operation of the Jet Propulsion Laboratory, 8 percent with or through other Government agencies, and 1 percent outside the United States.

#### Contracts Awarded to Private Industry

Ninety percent of the dollar value of procurement requests placed by NASA with other Government agencies resulted in contracts with industry awarded by those agencies on behalf of NASA. In addition, about 58 percent of the funds placed by NASA under the Jet Propulsion Laboratory contract resulted in subcontracts or purchases with business firms. In short, about 90 percent of NASA's procurement dollars was contracted to private industry.

Forty-five percent of the total direct awards to business firms represented competitive procurements, either through formal advertising or competitive negotiation. Fifty-five percent constituted noncompetitive procurements. With respect to the competitive procurements, 7 percent of the total awards represented new contracts and 38 percent constituted within scope modifications (in-

cremental funding actions and change orders) to contracts awarded competitively in prior years. Of the noncompetitive procurements, 13 percent of the total awards represented new contracts, and 42 percent constituted noncompetitive modifications to contracts awarded in prior years. With further respect to these noncompetitive procurements, 27 percent of the total awards represented follow-on after competition awards to companies that had been previously selected on a competitive basis to perform the original research and development on the applicable projects. In these instances, selection of another source would have required an extensive period of preparation for manufacturing and additional cost to the Government by reason of duplication of investment and preparation. The remaining 15 percent of noncompetitive procurements included awards arising from acceptable unsolicited proposals offering new ideas and concepts; awards to contractors having unique capabilities to meet particular requirements of the Government; and awards for sole source items.

Small business firms received \$93 million, or 7 percent of NASA's direct awards to business firms. However, most of the awards to business firms were for large continuing research and development contracts for major systems and major items of hardware. These are generally beyond the capability of small business firms on a prime contract basis. Of the \$261 million of new contracts of \$25,000 and over awarded to business firms during the six months, small business received \$37 million, or 14 percent.

In addition to the direct awards, small business received substantial subcontract awards from 85 of NASA's prime contractors participating in its Small Business Subcontracting Program. Total direct awards plus known subcontract awards aggregated \$168 million, or 13 percent of NASA's total awards to business during the period.

#### Geographical Distribution of Prime Contracts

Within the United States, NASA's prime contract awards were distributed among 48 States and the District of Columbia. Business firms in 41 States and the District of Columbia, and educational institutions and other nonprofit institutions in 46 States and the District of Columbia, participated in the awards. Four percent of the awards went to labor surplus areas located in 15 states.

#### Subcontracting

Subcontracting effected a further distribution of the prime contract awards. NASA's major prime contractors located in 26 States and the District of Columbia reported that their larger

subcontractor awards on NASA effort had gone to 1,038 subcontractors in 43 States and the District of Columbia, and that 74 percent of these subcontract dollars had crossed state lines.

#### Major Contract Awards

Among the major research and development contract awards by NASA during the period were the following:

1. Grumman Aerospace Corp., Bethpage, N.Y. NAS 9-1100. Development of Apollo lunar module. Awarded \$141 million; cumulative awards \$1,914 million.

2. North American Rockwell Corp., Downey, Calif. NAS 9-9224. Command service modules in a configuration for Apollo Applications Program. Awarded \$114 million; (new contract).

3. McDonnell Douglas Corp., Santa Monica, Calif. NAS 7-101. Design, develop and fabricate the S-IVB stage of the Saturn V vehicle and associated ground support equipment and provide launch support services. Awarded \$74 million; cumulative awards \$1,097 million.

4. North American Rockwell Corp., Downey, Calif., NAS 9-150. Design, develop and test Apollo command and service module. Awarded \$49 million; cumulative awards \$3,345 million.

5. The Boeing Company, New Orleans, La. NAS 8-5608. Design, develop and fabricate the S-IC stage of the Saturn V vehicle, construct facilities in support of the S-IC stage and provide launch support services. Awarded \$40 million; cumulative awards \$1,377 million.

6. Aerojet-General Corp., Sacramento, Calif. SNP-1. Design, develop and produce a nuclear powered rocket engine (NERVA). Awarded \$39 million; cumulative awards \$502 million.

7. International Business Machines Corp., Huntsville, Ala. NAS 8-14000. Fabrication, assembly and checkout of instrument units for Saturn I and Saturn V vehicles. Awarded \$34 million; cumulative awards \$325 million.

8. North American Rockwell Corp., Downey, Calif. NAS 7-200. Design, develop, fabricate and test the S-11 stage of the Saturn V vehicle and provide launch support services. Awarded \$32 million; cumulative awards \$1,269 million.

9. Martin Marietta Corp., Denver, Colo. NAS 8-24000. Payload integration for the Apollo Applications Program. Awarded \$32 million; cumulative awards \$57 million.

10. General Electric Company, Huntsville, Ala. NASW-410.

Apollo checkout equipment, related engineering design, quality and data management and engineering support; support services to Mississippi Test Facility. Awarded \$30 million; cumulative awards \$754 million.

11. North American Rockwell Corp., Canoga Park, Calif. NAS 8-19. Develop and procure 200,000-pound thrust J-2 rocket engine with supporting services and hardware. Awarded \$26 million; cumulative awards \$653 million.

12. TRW, Inc., Houston, Texas. NAS 9-8166. Apollo spacecraft systems analysis program. Awarded \$24 million; cumulative awards \$35 million.

13. Trans World Airlines, Inc., Kennedy Space Center, Fla. NAS 10-1242. Provide base support services at Kennedy Space Center. Awarded \$19 million; cumulative awards \$113 million.

14. Bendix Corporation, Kennedy Space Center, Fla. NAS 10-1600. Apollo launch support services at Kennedy Space Center. Awarded \$19 million; cumulative awards \$113 million.

15. General Dynamics Corp., San Diego, Calif. NAS 3-11811. Centaur program management and engineering services. Awarded \$15 million; (new contract).

16. The Boeing Company, Washington, D.C. NASW-1650. Apollo/Saturn V technical integration and evaluation. Awarded \$15 million; cumulative awards \$93 million.

17. McDonnell Douglas Corp., Santa Monica, Calif. NAS 7-623. Configure, checkout, prepare for launch and launch Delta space research vehicles. Awarded \$14 million; cumulative awards \$28 million.

18. Chrysler Corporation, New Orleans, La. NAS 8-4016. Fabricate, assembly, checkout and static test Saturn S-IB stage; provide product improvement program and spare parts support; modify areas of Michoud Plant assigned to contractor; provide launch support services. Awarded \$13 million; cumulative awards \$497 million.

19. McDonnell Douglas Corp., St. Louis, Mo. NAS 9-6555. Design, fabricate and deliver orbital workshop (modified Saturn S-IVB stages) and airlock modules for Apollo Applications Program and provide operational support. Awarded \$13 million; cumulative awards \$40 million.

20. Bendix Corporation, Owings Mills, Md. NAS 8-10800. Maintenance and operation of STADAN. Awarded \$11 million; (new contract).

## Major Contractors

The 25 contractors receiving the largest direct awards (net value) during the period were as follows:

<i>Contractor &amp; Place of Contract Performance</i>	<i>Thousands</i>
1. North American Rockwell Corp. *Downey, Calif.	\$236,537
2. Grumman Aerospace Corp. *Bethpage, N.Y.	147,291
3. McDonnell Douglas Corp. *Santa Monica, Calif.	114,412
4. General Electric Company *King of Prussia, Pa.	61,585
5. Boeing Company *Kennedy Space Center, Fla.	59,372
6. Int'l. Business Machines Corp. *Huntsville, Ala.	59,300
7. Bendix Corporation *Owings Mills, Md.	53,205
8. Aerojet-General Corp. *Sacramento, Calif.	48,301
9. Martin Marietta Corp. *Denver, Colo.	39,920
10. Lockheed Aircraft Corp. *Houston, Texas	25,731
11. General Dynamics Corp. *San Diego, Calif.	25,544
12. Trans World Airlines, Inc. *Kennedy Space Center, Fla.	21,553
13. TRW, Inc. *Houston, Texas	20,865
14. Service Technology Corp. *Houston, Texas	19,419
15. RCA Corporation *Camden, N.J.	18,567
16. United Aircraft Corp. *Windsor Locks, Conn.	16,628
17. Sperry Rand Corp. *Huntsville, Ala.	16,158

<i>Contractor &amp; Place of Contract Performance</i>		<i>Thousands</i>
18. Chrysler Corporation		\$15,622
*New Orleans, La.		
19. Philco-Ford Corp.		11,235
*Houston, Texas		
20. General Motors Corp.		10,067
*Milwaukee, Wisc.		
21. Northrop Corp.		7,469
*Huntsville, Ala.		
22. Brown/Northrop (Joint Venture)		6,801
Houston, Texas		
23. Catalytic-Dow (Joint Venture)		6,619
Kennedy Space Center, Fla.		
24. Bellcomm, Inc.		6,062
Washington, D.C.		
25. Honeywell, Inc.		5,419
*St. Petersburg, Fla.		

\* Awards during year represent awards on several contracts which have different principal places of performance. The place shown is that which has the largest amount of awards.

## LABOR RELATIONS

During this period, strikes on construction contracts caused an increase in lost man-days over the preceding six months. Man-days lost during the first half of 1969 amounted to 2,421 as compared to 885 man-days lost during the last six months of 1968. A single area strike of carpenters caused the loss of 1,860 man-days at one Center.

Only 24 man-days were lost on industrial contracts—a significant drop from the 3,579 man-days lost during the last half of 1968.

Strikes resulting from breakdown in negotiations of labor agreements on NASA industrial support contracts caused the unusual number of lost man-days during the preceding period. Settlement of disagreements and grievances brought stability to the labor situation.

## RELIABILITY And QUALITY ASSURANCE

The reliability and quality assurance lessons learned in the Atlas-Centaur ATS-D launch vehicle failure and actions taken to prevent reoccurrence were distributed NASA-wide. Similar follow-up action on the Delta 59 INTELSAT F-1 failure was ex-

panded with R&QA participation in the investigation of the Delta 71 INTELSAT F-5 and Delta 73 Pioneer failures. The R&QA aspects of Thor and Thor Delta vehicle programs were under study through participation in the OSSA Senior Review Board. Action was taken to tighten contractual requirements for quality assurance on the Delta program.

Basic contractual quality assurance requirements for NASA aeronautical and space systems were updated and revised with issuance of NHB NASA Handbook 5300.4(1B). Similarly, basic reliability program requirements and microelectronics reliability requirements undergoing final review for publication. Companion requirements in the NASA Procurement Regulation either have been revised or are under revision to be consistent with current and improved procurement practices.

### RELATIONSHIPS With Other GOVERNMENT AGENCIES

NASA continued to assist and receive support from other Federal agencies engaged in, or using the results of, aerospace-related research and development.

In its relationships with the Department of Defense, NASA took part in a number of significant developments. To replace the terminated supersonic research programs conducted on the B-70 and the X-15, NASA and the Air Force combined their interests in a new joint effort to use two surplus YF-12 aircraft. By a memorandum of understanding (signed on June 5, 1969), the two agencies agreed to conduct a two-phase research, development, and test program. Phase one is to be oriented to Air Force interests in the development of operational techniques involving supersonic aircraft. Phase two is to encompass NASA technology objectives which support development of the supersonic transport and a new generation of supersonic military aircraft.

The Secretary of the Navy requested NASA to conduct an independent evaluation of its new fighter aircraft, the F-14, now in development. NASA will study the contractor's design to determine the performance capabilities of the aircraft.

One of the coordinating mechanisms between NASA and the Department of Defense is the Aeronautics and Astronautics Coordinating Board (AACB) and its six panels—Aeronautics, Launch Vehicles, Manned Space Flight, Supporting Research and Technology, Space Flight Ground Environment, and Unmanned Spacecraft. The panels continued their activities during the period.

In January, the Aeronautics Panel submitted the Report on National Facilities Needed to Support Foreseeable Aeronautical Re-

search and Development Programs to the AACB. Subsequently, the Panel began developing a set of priorities, costs, and schedules outlining the necessary actions to acquire selected facilities.

By direction of the President, a Space Task Group (STG) composed of the Vice President, the President's Science Adviser, and representatives of DoD and NASA was formed to provide the Administration with an increased understanding of the national space program, its plans and goals. Coordination of the DOD and NASA STG activities was reviewed by the Unmanned Spacecraft Panel.

The Space Flight Ground Experimental Panel reported on its study of the Data Relay Satellite (DRS) and the status of current studies to establish full coordination of systems evaluations and developments. The Board recongized the complexity of the DRS concept. Further work was underway to develop a coordinated study plan for Data Relay Satellite Systems.

The Manned Space Flight Panel completed a joint review of Air Force and NASA space transportation system studies.

NASA has continued informal relationships with the Department of Health, Education, and Welfare (HEW) to consider areas of mutual interest. One such area involved the role communications satellite technology might play in advancing educational and cultural objectives (instructional TV in schools, public TV, and medical education for practicing physicians). NASA looks to the Office of Education to evaluate the educational aspects of proposals to use its satellites for educational demonstrations or experiments. On the other hand, HEW has referred to NASA for comment proposals they have received involving potential use of communications satellites.

In accordance with the provisions of the Communications Satellite Act of 1963, NASA advised the Federal Communications Commission (FCC) on some of the technical aspects of communications satellite systems, including launch vehicle capability and costs. NASA also consulted with the FCC concerning possible experiments with potential domestic uses of communications satellites. In this connection, NASA briefed representatives of the FCC, HEW, The National Library of Medicine, the Office of the Director of Telecommunications of Management, and the U.S. Information Agency. NASA also provided advice and assistance to the Office of Telecommunications Management in connection with the Conference on Definitive Arrangements for the International Telecommunications Satellite Consortium (INTELSAT).

NASA assisted the Department of Transportation in exploring and evaluating rapid transit systems for urban centers.

### NASA SAFETY PROGRAM

During the past eighteen months, NASA greatly increased its emphasis on safety in general and system safety in particular. The Agency formalized and strengthened current safety activities and developed many new concepts, methods, and organizations.

The overall NASA safety program is being implemented through three basic publications: Safety Policy Directive NPD 1701.1, NASA Safety Manual 1700.1, Volume I, and a special safety section in the NASA Procurement Regulation.

*The NASA Policy Directive* defines four broad areas of safety—Industrial Safety, Public Safety, Aircraft Safety, and System Safety. Industrial Safety is oriented to protect people and equipment in the industrial environment. Public Safety addresses NASA relationships with the public. Aircraft Safety has to do with the safe operation of all NASA aircraft, including operational and experimental types. System Safety is concerned with the safety of aerospace systems, both manned and automated. This Policy Directive is in effect the charter of the NASA Safety Office.

*The NASA Safety Manual* is a directive that sets forth the overall internal NASA safety requirements for the Agency.

*The Procurement Directive* includes the contracting requirements to be imposed in either facility or space hardware procurement contracts.

All of these publications are structured to support the NASA functional management concept. The NASA Safety Office and the respective safety organizations operate in a staff capacity throughout the Agency, providing the field installation director and the individual project manager a professional resource that gives visibility to the risks he is assuming.

These basic publications were being supplemented with additional guides, management instructions, and handbooks to put into being an effective safety program—one flexible enough to accommodate the NASA mission which is generally research and development oriented.

The focal point for the NASA Safety Program is the NASA Safety Director, who creates the overall safety policy requirements and guidelines for the Agency. It is his responsibility to evaluate the various field installation and project safety activities, measuring both the performance of the safety effort against the stated

requirements, and the effectiveness of the safety requirements themselves.

The efforts of the NASA Safety Office continued to show noteworthy results. The three previously mentioned publications were coordinated throughout the Agency and were either published or in process of publication. Sub-tier handbooks and Management Instructions were being developed for early publication.

A formal method of safety evaluations was developed and reviews were being conducted on a regularly scheduled basis. The evaluations reveal that the safety program is growing and maturing. Professionals are being assigned as safety officials, charged with the responsibility for conducting the safety-risk evaluation programs. Field installation directors and program managers are beginning to recognize the need for risk visibility and are using the guidance, assistance, and encouragement of the safety program.

## Appendix A

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### Congressional Committees on Aeronautics and Space

(January 1–June 30, 1969)

#### Senate Committee on Aeronautical and Space Sciences

CLINTON P. ANDERSON, New Mexico, <i>Chairman</i>	SPESSARD L. HOLLAND, Florida
RICHARD B. RUSSELL, Georgia	MARGARET CHASE SMITH, Maine
WARREN G. MAGNUSON, Washington	CARL T. CURTIS, Nebraska
STUART SYMINGTON, Missouri	MARK O. HATFIELD, Oregon
JOHN STENNIS, Mississippi	BARRY GOLDWATER, Arizona
STEPHEN M. YOUNG, Ohio	CHARLES MCC. MATHIAS, JR., Maryland
THOMAS J. DODD, Connecticut	WILLIAM B. SAXBE, Ohio
HOWARD W. CANNON, Nevada	

#### House Committee on Science and Astronautics

GEORGE P. MILLER, California, <i>Chairman</i>	JAMES W. SYMINGTON, Missouri
OLIN E. TEAGUE, Texas	EDWARD J. KOCH, New York
JOSEPH E. KARTH, Minnesota	JAMES G. FULTON, Pennsylvania
KEN HECHLER, West Virginia	CHARLES A. MOSHER, Ohio
EMILIO Q. DADDARIO, Connecticut	RICHARD L. ROUDEBUSH, Indiana
JOHN W. DAVIS, Georgia	ALPHONZO BELL, California
THOMAS N. DOWNING, Virginia	THOMAS M. PELLY, Washington
JOE D. WAGGONER, JR., Louisiana	JOHN W. WYDLER, New York
DON FUQUA, Florida	GUY VANDER JAGT, Michigan
GEORGE E. BROWN, JR., California	LARRY WINN, JR., Kansas
EARLE CABELL, Texas	JERRY L. PETTIS, California
BERTRAM L. PODELL, New York	DONALD E. LUKENS, Ohio
WAYNE N. ASPINALL, Colorado	ROBERT D. PRICE, Texas
ROY A. TAYLOR, North Carolina	LOWELL P. WEICKER, JR., Connecticut
HENRY HELSTOSKI, New Jersey	LOUIS FREY, JR., Florida
MARIO BIAGGI, New York	BARRY GOLDWATER, JR., California

## Appendix B

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### National Aeronautics and Space Council

(January 1–June 30, 1969)

SPIRO T. AGNEW, *Chairman*  
*Vice President of the United States*

WILLIAM P. ROGERS  
*Secretary of State*

MELVIN R. LAIRD  
*Secretary of Defense*

THOMAS O. PAINE, *Administrator*  
*National Aeronautics and Space Administration*

GLENN T. SEABORG, *Chairman*  
*Atomic Energy Commission*

*Executive Secretary*  
(Vacant)\*

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\* Astronaut William A. Anders was nominated as Executive Secretary by the President on May 14, confirmed by the Senate June 18, and took office September 2, after completing his assignment as a member of the Apollo 11 back-up crew.

## Appendix C

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### Principal NASA Officials at Washington Headquarters

(June 30, 1969)

DR. THOMAS O. PAINE	Administrator
Vacant	Deputy Administrator
DR. HOMER E. NEWELL	Associate Administrator
WILLIS H. SHAPLEY	Associate Deputy Administrator
BERNARD MORITZ (Acting)	Associate Administrator for Organization and Management
WILLIAM E. LILLY	Assistant Administrator for Administration
GEORGE J. VECCHIETTI (Acting)	Assistant Administrator for Industry Affairs
BERNARD MORITZ	Assistant Administrator for Special Contracts Negotiation and Review
MELVIN S. DAY (Acting)	Assistant Administrator for Technology Utilization
FRANCIS B. SMITH	Assistant Administrator for University Affairs
DEMARQUIS D. WYATT	Assistant Administrator for Program Plans and Analysis
DR. ALFRED J. EGGERS, JR.	Assistant Administrator for Policy
JACOB E. SMART	Assistant Administrator for DOD and Interagency Affairs
ADM. CHARLES E. WEAKLEY, USN (Ret.)	Assistant Administrator for Management Development
PAUL G. DEMBLING	General Counsel
ARNOLD W. FRUTKIN	Assistant Administrator for International Affairs
ROBERT F. ALLNUTT	Assistant Administrator for Legislative Affairs
JULIAN SCHEER	Assistant Administrator for Public Affairs
DR. GEORGE E. MUELLER	Associate Administrator for Manned Space Flight
DR. JOHN E. NAUGLE	Associate Administrator for Space Science and Applications
GERALD M. TRUSZYNSKI	Associate Administrator for Tracking and Data Acquisition
BRUCE T. LUNDIN (Acting)	Associate Administrator for Ad- vanced Research and Technology

(Telephone information: 936-7101)

## Appendix D

### Current Official Mailing Addresses for Field Installations.

(June 30, 1969)

Installation and telephone number	Official	Address
Ames Research Center; 415-961-1111.	Dr. Hans M. Mark, Director	Moffett Field, Calif. 94035.
Electronic Research Center; 617-494-2000.	Mr. James C. Elms, Director	575 Technology Square, Cambridge, Mass. 02139.
Flight Research Center; 805-258-3311.	Mr. Paul Bikle, Director	Post Office Box 273, Edwards, Calif. 93523.
Goddard Space Flight Center; 301-982-5042.	Dr. John F. Clark, Director	Greenbelt, Md. 20771.
Goddard Institute for Space Studies; 212-UN6-3600.	Dr. Robert Jastrow, Director	2880 Broadway, New York, N.Y. 10025.
Jet Propulsion Laboratory; 213-354-4321.	Dr. W. H. Pickering, Director	4800 Oak Grove Dr., Pasadena, Calif. 91103.
John F. Kennedy Space Center; 305-867-7113.	Dr. Kurt H. Debus, Director	Kennedy Space Center, Fla. 32899.
Langley Research Center; 703-827-1110.	Mr. Edgar M. Cortright, Director	Langley Station, Hampton, Va. 23365.
Lewis Research Center, 216-433-4000.	Dr. Abe Silverstein, Director	21000 Brookpark Rd., Cleveland, Ohio 44135.
Manned Spacecraft Center; 713-HU3-8111.	Dr. Robert R. Gilruth, Director	Houston, Tex. 77058.
George C. Marshall Space Flight Center; 205-453-3131.	Dr. Wernher von Braun, Director	Marshall Space Flight Center, Ala. 35812.
Michoud Assembly Facility; 504-255-3311.	Dr. George N. Constan, Manager	Post Office Box 29300, New Orleans, La. 70129.
Mississippi Test Facility; 601-688-2211.	Mr. Jackson M. Balch, Manager	Bay St. Louis, Miss. 39520.
KSC Western Test Range Operations Division; 805-866-1611.	Mr. H. R. Van Goey, Chief	Post Office Box 425, Lompac, Calif. 93433.
Plum Brook Station; 419-625-1128.	Mr. Alan D. Johnson, Director	Sandusky, Ohio 44871.
Wallops Station; 703-VA4-3411--	Mr. Robert L. Krieger, Director	Wallops Island, Va. 23337.

## Appendix E

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### NASA's Historical Advisory Committee

(June 30, 1969)

*Chairman:* MELVIN KRANZBERG, Western Reserve University and Executive Secretary of the Society for the History of Technology

#### MEMBERS

RAYMOND BISPLINGHOFF, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology

JAMES LEA CATE, Department of History, University of Chicago

EARL DELONG, Dean, School of Government and Public Administration, The American University

A. HUNTER DUPREE, Department of History, University of California (Berkeley)

JOE B. FRANTZ, Department of History, University of Texas

LOUIS MORTON, Department of History, Dartmouth College

ROBERT L. PERRY, Economics Division, The RAND Corporation

*Executive Secretary:* EUGENE M. EMME, NASA Historian

Appendix F

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NASA's Inventions and Contributions Board

(June 30, 1969)

Chairman -----	ERNEST W. BRACKETT
Vice Chairman -----	LEONARD RAWICZ
Director of the Staff -----	FRANCIS W. KEMMETT
Members -----	MELVIN S. DAY
	C. GUY FERGUSON
	HARVEY HALL
	ARTHUR D. HOLZMAN
	CLARENCE R. MORRISON
	JOHN B. PARKINSON
	JAMES O. SPRIGGS

## Appendix G

### Patent Waivers Granted and Denied for Separate Inventions Upon Recommendation of the Agency's Inventions and Contributions Board

(January 1-June 30, 1969)

Invention	Petitioner	Action on petition
Extendable Boom -----	Westinghouse Electric Corp.---	Granted.
Self-Forming Boom Retracting and Deploying Apparatus.	---- do. -----	Do.
Constant Wear Ventilated Bump Hat -----	United Aircraft Corporation--	Granted.
Pulse Shape Discriminating Circuit -----	University of New Hampshire--	Denied.
Metal Containing Polymers from Cyclic Tetrameric ---	W. R. Grace and Company --	Do.
Novel Flame Retardant Composition -----	North American Rockwell Corporation.	Granted.
Fastener Tool -----	Aerojet-General Corporation -	Do.
Solid State Device -----	Massachusetts Institute of Technology.	Do.
A Regenerable CO <sub>2</sub> Removal Process -----	MSA Research Corporation --	Granted.
Method of Impregnating Porous Tungsten -----	Hughes Aircraft Company --	Granted.
Method of Producing Finite Fringes in Holograms ----	TRW, Incorporated -----	Do.
High Order Holographic Interferometry -----	---- do. -----	Do.
Fringe Interpolation Technique -----	---- do. -----	Do.
Color Phosphor Screen Composition -----	ITT Industrial Laboratories --	Do.
Improved Thermal Treatment of Aluminum Base Alloy Article.	Tyco Laboratories, Inc. ----	Do.
Helimeter Control System -----	TRW, Inc. -----	Do.
Non-Flammable Long Term Comfort Pads -----	North American Rockwell Corp.	Do.
Fuel Cell -----	McDonnell-Douglas Corp. ---	Do.
Ion Exchange Membrane and Fuel Cell Containing Same.	---- do. -----	Do.
Ion Exchange Membrane Production -----	---- do. -----	Do.
Automatic Optometer -----	Stanford Research Institute --	Granted.
Electrochemical Cell having Barrier with Microporous Openings.	Electrochimica Corporation --	Do.
Protective Garmet Ventilation System -----	United Aircraft Corporation--	Do.
Convolved Bi-Tape Foreshortened Knee -----	---- do. -----	Do.
Connector -----	---- do. -----	Do.
Thermal Coated Booms for Spacecraft -----	Westinghouse Electric Corp.---	Do.
Dual Mode Manual Controller -----	ITT Corporation -----	Do.
Emergency Space Suit Helmet -----	United Aircraft Corporation--	Do.
Improved Alkaline Cell -----	Leesona Corporation -----	Do.
A Method of Synthesizing Condensed Ring Polymers --	Avco Corporation/Space Systems Division.	Do.
Ring Laser Inertial Angle Encoder -----	Massachusetts Institute of Technology.	Do.

Invention	Petitioner	Action on petition
Pressure-Variable Orifice (Hydraulic) -----	North American Rockwell Corporation.	Do.
A Traveling Wave Two Port Solid State Amplifier using the Transferred Electron Effect.	Stanford University -----	Do.
Improved Catalysts for Preparation of Poly-2 Oxazolidones.	Monsanto Research Corp. ---	Granted.
Electrohydrodynamic Induction Flowmeter and Conductivity Measuring Device.	Massachusetts Institute of Technology.	Do.
Low Light Level TV Camera -----	Singer-General Precision, Inc..	Do.
Dual Field Optical Tracking Objective -----	ITT Corporation -----	Do.
Fatigue Testing Machine -----	Littleton Research and Engineering Corporation.	Do.
Method and Apparatus for Employing Vibratory Energy for Wrenching (Ultrasonic Torque Wrench).	Tecnidyne, Incorporated ----	Denied.
Improved Magnetron Ion Source -----	Norton Company/Norton Research Corporation.	Granted.
Helmet Latching and Attaching Ring -----	United Aircraft Corporation..	Do.
Restraining Mechanism -----	--- do. -----	Do.
Fabrication of Compound Semiconductor Films -----	Massachusetts Institute of Technology.	Do.
Structural Adhesives Applicable Throughout Broad Temperature Range.	Monsanto Research Corp. ---	Do.
Memory System Employing Capacitance Storage Means.	Massachusetts Institute of Technology.	Granted.
Composite Thermal Radiation Shield for Multilayer Insulations.	Arthur D. Little, Inc. -----	Do.
Improved Van Atta Array -----	MacDowell Associates Inc. ---	Do.
Instrument for Permeation and Diffusion Studies ----	Stanford Research Institute..	Do.
Gas Flowmeter with Safety Release -----	California Institute of Technology.	Do.
Piezoelectric Linear Actuator -----	Fairchild Technology Corp. (Astrosystems International Incorporated).	Do.
SSR Listen-in Feature for Proximity Warning -----	George B. Litchford -----	Do.
Heat Pipe Type Devices which will Re-Start after Solidification of Working Fluid.	TRW, Inc. -----	Do.
Multi-Chamber Controllable Heat Pipe -----	--- do. -----	Do.
High Efficiency, High Frequency, Magnetic Deflection Driver.	Frederick L. Schaff -----	Do.
Method and Apparatus for Averaging Signals -----	Stanford Research Institute..	Granted.
Method for Controlling Zinc Dendrite Growth -----	Yardney Electric Corporation..	Do.

## Appendix H

### Patent Waivers Granted and Denied for all Inventions Made during Performance of Contract Upon Recommendation of the Agency's Inventions and Contributions Board

(January 1-June 30, 1969)

Contract description <sup>1</sup>	Petitioner	Action on petition
Flight Qualification of Improved Fuel Cell Electrical Power Supply.	Alis-Chalmers Manufacturing Company.	Granted.
Demonstrate Feasibility of Carb-I-Tex Material for Solid Rocket Motors with Long Burning Times.	The Carborundum Company--	Do.
R&D, Design, and Deliver One Qualification Production Model and Seven Production Activity History Display Recorders.	National Cash Register Co. --	Do.
Cell Contact Deposition Parameter Study -----	Texas Instruments, Inc. -- --	Do.
Design, Develop, Fabricate, Test and Deliver Two Cesium Iodide Beam-Splitters for an Interferometer Spectrometer.	--- do. -----	Do.
Design and Develop an Advanced Eye Oximeter -----	Space Sciences, Incorporated --	Denied.
X-Ray Equipment for Lunar Receiving Laboratory ---	North American Philips Company, Incorporated.	Granted.
Experiment Definition Study of the Position Location and Aircraft Communications Equipment Concept.	Texas Instruments, Inc. -----	Denied.
Single Frequency Argon Ion Laser -----	Spacerays, Incorporated -----	Granted.
Study to Evaluate the Technical Feasibility of Multiple Reserve Power Sources.	Esso Research and Engineering Company.	Do.
Design, Fabricate and Test a Foil Gas Bearing Test Rig.	Ampex Corporation -----	Do.
Kinetic Flow Performance in Nozzles -----	United Aircraft Corporation--	Denied.
R&D of an Electric Thruster Power Conditioning System.	Hughes Aircraft Company ---	Granted.
Design and Development of a Fluidic Control System for Liquid Cooled Garments.	Honeywell, Inc. -----	Denied.
Radiation Measurements of Induction Heated Plasmas--	Humphreys Corporation/ TAFE Division.	Granted.
Induction Plasma Nozzle Tests -----	--- do. -----	Do.
Curved Porous Wall Induction Torch Tests -----	--- do. -----	Do.
Improvement In Laser Gyro Technology -----	Honeywell, Incorporated/ Systems and Research Division.	Do.
High Energy Density Primary Battery -----	Honeywell, Incorporated ----	Do.
Three Axis Integrated Rate Gyroscope System -----	--- do. -----	Do.
Infrared Interferometer Spectrometer -----	Texas Instruments, Inc. -----	Do.
Infrared Interferometer Spectrometer -----	--- do. -----	Do.
Design, Develop, Fabricate, Assemble and Test Computer Equipment in the Nature of a Data Storage	--- do -----	Do.

<sup>1</sup> See footnote at end of table.

Contract description <sup>1</sup>	Petitioner	Action on petition
Subsystem and Associated Support Equipment. Design and Fabricate and Test a Flight Telemetry Subsystem and Operational Support Equipment.	Texas Instruments, Inc.	Granted.
Propulsion Study of Horizontally Opposed Piston Internal Combustion Engines for General Aircraft Systems.	AVCO Corporation/ Lycoming Division.	Granted.
Threshold Logic Implementation of a Modular Computer System Design.	Radio Corporation of America.	Do.
Memory Arrays Using Complementary Metal Oxide Semiconductor-Silicon-On-Sapphire.	do. -----	Do.
64 Bit Monolithic Complementary MOSFET NORO Random Access Memory.	do. -----	Do.
Design and Fabricate Wave Forming Circuits Intended for use in Static Inverter Development.	do. -----	Do.
Study, Define, Design, Fabricate and Deliver 25 each Arithmetic Units for Space Flight Computer Applications.	Westinghouse Electric Corp.---	Do.
Evaluation of TPM-217 Thermoelectric Material -----	3M Company -----	Do.
Feasibility Study ICICLE System -----	Radio Corporation of America.	Do.

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Petitions deferred

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Texas Instruments, Incorporated  
Hughes Aircraft Company  
Radio Corporation of America

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<sup>1</sup> Waiver before execution of contract.

## Appendix I

### Scientific and Technical Contributions Recognized by the Agency's Inventions and Contributions Board

(January 1–June 30, 1969)

Awards Granted Under Provisions of Section 306 of the Space Act of 1958

Contribution	Inventor (s)	Employer
Cooling Means For Linear Beam Tubes.*	Lloyd J. Derr -----	Jet Propulsion Laboratory.
Convoluting Device For Forming Convolutions And The Like.*	Raymond E. Michel, Dallas E. Nelson.	Do.
High Voltage Transistor Circuit* ---	James S. Lee -----	Hughes Aircraft Company.
Telemetry Word Forming Unit* ----	Hoyt Holmes Nelson -----	General Precision Inc.
DC—Coupled, Non-Inverting One Shot Multivibrator.*	Francis M. Pan -----	Hughes Aircraft Company.
High Strength Pressure Vessel And Method.*	Benjamin Roth -----	North American Rockwell Corporation.
Sealed Separable Connector* -----	Robert M. Bamford -----	Jet Propulsion Laboratory.
Data Compression Processor* -----	Tage O. Anderson -----	Do.
Multiple Orifice Throttle Valve* ----	Louis A. Rosales, John A. Fitton, Jr.	TRW, Inc.
Tuning Arrangement For A Magnetron Or The Like.*	Vincent J. Martucci -----	Metcom, Inc.
Second Surface Mirrors For Solar Cell Array.*	Ralph R. Scott -----	Radio Corporation of America.
Thermocouple Probe Control For Welding Torch.*	William M. McCampbell --- George W. Cook -----	Marshall Space Flight Center Merrick Engineering Inc.
Apparatus And Method For Testing Polymeric Materials.*	Raffaele F. Muraca -----	Stanford Research Institute.
Rocket Nozzle Test Method* -----	Ellis G. Estes -----	McDonnell Douglas Corp.
Counter* -----	William E. Baumer, John D. Timm.	Computer Control Company.
Propellant Mass Distribution Metering Apparatus.*	Ralph A. Ayvazian -----	North American Rockwell Corporation.
Broadband Frequency Discriminator.*	Samuel Sabaroff -----	Hughes Aircraft Company.
Difference Circuit* -----	John R. Morris -----	Do.
Semi-Toroidal Diaphragm Cavitating Valve.*	Albert L. Young -----	TRW, Inc.
Control Valve And Co-Axial Variable Injector.*	Louis A. Rosales, Albert L. Young.	Do.
Method And Apparatus For Producing Fine Particles.*	Robert H. Globus -----	Aerojet-General Corporation.
Rapid Response Proportional Electronic Exposure Control.*	Melvin L. Zwillenberg, Donald K. Kuehl.	United Aircraft Research Laboratories.

\* Minimum award for patent application.

Contribution	Inventor (s)	Employer
Video Processor* -----	James W. Wood -----	General Precision, Inc.
Thermobulb Mount* -----	Robert B. Schaus -----	North American Rockwell Corporation.
Gas Regulator* -----	Harry J. King, Seiji Kami -----	Hughes Research Laboratories.
Laser Camera And Diffusion Filter Therefor.* -----	Mark J. Olsasky -----	North American Rockwell Corporation.
Oscillating Particle Separator* -----	Douglas G. Ritchie -----	Electro-Optical Systems, Inc.
Three Axis Torque Measuring Fixture.* -----	Howard A. Herzog, William Packard.	The Bendix Corporation.
External Flow Jet Flap -----	John P. Campbell -----	Langley Research Center.
A Data Transmission System -----	Philip A. Jewell -----	Jet Propulsion Laboratory.
Data Compressor -----	Edward C. Posner, Isidore Eisenberger, Tage O. Anderson, Warren A. Lushbaugh.	Do.
Data Compression System -----	Irwin M. Jacobs -----	Do.
Operational Integrator -----	Erno P. Lutz -----	Do.
FM TV Synchronization System ---	Frederick P. Landauer -----	Do.
A High Impact Antenna -----	Kenneth E. Woo -----	Do.
Logic Switching Device Having Isolated Output.	Daniel M. Bergens, Edward L. Bonin.	Do.
Multi-Feed Cone Cassegrain Antenna.	Charles T. Stelzried, Gerald S. Levy, Masakazu Smoot Katow.	Do.
Apparatus For Detecting Radio-activity Of Flowing Fluids.	James K. Martin -----	National Research Council.
Magnetic Recording Head And Method Of Making Same.	James D. Kern, Valdimar W. Vodička.	Applied Magnetics Corp.
Transient Video Signal Recording With Expanded Playback.	Ronald C. Sander -----	U. S. Air Force
Rocket Engine Thrust Vector Deviation Measurement Device.*	Ronald J. Hruby -----	Ames Research Center.
Piezoelectric Pump* -----	Herbert Shieber, Kirke Leonard.	TRW Systems Group, TRW, Inc.
Multiple Pellet Test Fixture* -----	Robert F. Anderson -----	Honeywell Inc.
Phototropic Composition Of Matter*.	Anthony J. Nasuti -----	Do.
	John B. Schutt, Joe A. Colony.	Goddard Space Flight Center
	Donald R. Lepp -----	Taag Design Inc.
Inspection Gage For Boss -----	Wallace J. Jordan -----	Marshall Space Flight Center
	James T. Whisenant -----	Brown Engineering Division, Teledyne Inc.
Space Simulation And Radiative Property Testing System And Method.*	Frank E. Badin, Franklin D. Farnsworth	Fairchild Hiller Corporation.
Light Detection Instrument -----	Emmette W. Chappelle, Duane G. Hoffman	Hazleton Laboratories Inc.
Anomalous Count Prevention For Shift Counters.	Richard W. Ahrons -----	Radio Corporation of America.
Cermet And Method Of Making Same.*	Alexis I. Kaznoff, Mickey O. Marlowe.	General Electric Company.
Optical Tracking Mount -----	Josef M. Boehm -----	Marshall Space Flight Center
	M. Roy Broussard -----	Sperry Rand Corporation.
Constructing Inexpensive Automatic Picture-Transmission Ground Stations.	Charles H. Vermillion -----	Goddard Space Flight Center.
Converging-Barrel Plasma Accelerator.	Dah Yu Cheng -----	National Research Council.
Digital Frequency Discriminator* --	William J. Reid -----	Motorola, Inc.
Electrical Voltage Multiplier System.*	Charles R. Savelle, Jr. ----	Spaco, Inc.

\* Minimum award for patent application.

Contribution	Inventor(s)	Employer
Purge Device For Thrust Engines --	Vincent M. Partsch -----	North American Rockwell Corporation.
Friction Measuring Apparatus -----	Warren G. Clement -----	Jet Propulsion Laboratory.
Laminar Flow Enhancement* -----	Ralph A. Ayvazian -----	North American Rockwell Corporation.
Method And Device For Forming Extrusions.*	James G. Hunt, Roy W. Rice.	The Boeing Company.
Sight Switch Using An Infrared Source And Sensor.	Charles L. Nork -----	Space, Inc.
Failure Sensing And Protection Circuit For Converter Networks.*	Kenneth J. Jensen -----	Honeywell Inc.
Multiple Varactor Frequency Doubler.*	Joseph H. Habra -----	TRW, Inc.
Dual-Mode Range Acquisition System.*	Stanley W. Attwood, Arthur J. Kline, Jr.	Motorola, Inc.
Spectroscope Equipment -----	Ralph A. Goodwin, Edgar D. Ball.	Trident Engineering Associates.
Dual Solid Cryogenes For Spacecraft Refrigeration.*	Robert P. Caren, Robert M. Coston.	Lockheed Missiles and Space Company.
Panelized High-Performance Multi-layer Insulation.*	James M. Stuckey ----- Ralph A. Burkley, Clem B. Shriver.	Marshall Space Flight Center Goodyear Aerospace Corporation.
Waveshaping Circuit Apparatus* ---	Thomas P. Harper -----	IBM Corporation.
Nickel-Base Alloy -----	John C. Freche, William J. Waters.	Lewis Research Center.
Apparatus For Measuring Conductivity And Velocity Of Plasma.	Vernon J. Rossow -----	Ames Research Center.
Exposure System For Animals -----	Phillip D. Quattrone, Robert W. Staley.	Do.
Antenna Feed System* -----	William Korvin, Milton K. Mills.	Goddard Space Flight Center.
Method Of Planetary Atmospheric Investigation Using A Split-Trajectory Dual Flyby Mode.*	John M. Coogan -----	Ames Research Center.
Two Force Component Measuring Device.*	Earl D. Knechtel, William C. Pitts.	Do.
Propellant Feed Isolator -----	Shigeo Nakanishi -----	Lewis Research Center.
Microbalance* -----	Earl D. Knechtel -----	Ames Research Center.
Feedback Integrator With Grounded Capacitor.	Gordon J. Deboo -----	Do.
Hypervelocity Gun -----	Thomas N. Canning -----	Do.
Modulation Multiplier* -----	A. William Carlson, Charles A. Furciniti.	Northeastern University.
Target Acquisition Antenna* -----	Joseph P. Grabowski, Walter E. Powell, Jr.	Radio Corporation of America.
Frequency Selective Switch* -----	Frederick L. Lanphear, William H. Sheppard.	Do.
Positive And Negative Work Cylinder.	Berge Hagopian -----	North American Rockwell Corporation.
Stirring Apparatus For Plural Test Tubes.	Ira J. Strong, Henry A. Leon.	Ames Research Center.
ACE S/C Electronic Checkout System.	Gary J. Woods, Walter E. Parsons, Harold G. Johnson, G. Merritt Preston, Thomas S. Walton, Jacob C. Moser.	John F. Kennedy Space Center.
Method Of Making Tubes -----	John J. Park -----	Goddard Space Flight Center.
Improved McLeod Pressure Gage* ---	Milton C. Kells -----	Ames Research Center.

\* Minimum award for patent application.

Contribution	Inventor (s)	Employer
Telemeter Adaptable For Implanting In An Animal.	Thomas B. Fryer -----	Ames Research Center.
Hand Cutter And Sealer For Fusible Fabrics.*	Robert J. Carmody -----	Marshall Space Flight Center.
Pneumatic Oscillator* -----	Miles O. Dustin -----	Lewis Research Center.
Transducer Circuit And Catheter Transducer.	Dean R. Harrison, William J. Kerwin.	Ames Research Center.
Variable Stiffness Polymeric Damper.	Jerome J. Lohr -----	Do.
Control Device* -----	Nozomu Iwasaki, Wayne O. Hadland.	Do.
Attitude Controls For VTOL Aircraft.	Frank A. Pauli -----	Do.
Gyrator Circuit Employing Operational Amplifiers.	Gordon J. Deboo -----	Do.
Angular Position And Velocity Sensing Apparatus.	Leo J. Veillette -----	Goddard Space Flight Center.
Turn-On Transient Limiter -----	Frederick C. Hallberg -----	Do.
Optical Monitor Panel* -----	Francis D. Griffin -----	John F. Kennedy Space Center.
Precision Stepping Drive -----	Walter E. Kaspareck -----	Marshall Space Flight Center.

\* Minimum award for patent application.

## Appendix J

### Awards Granted NASA Employees Under Provisions of the Incentive Awards Act of 1954

(January 1-June 30, 1969)

Contribution	Inventor(s)
<i>Ames Research Center:</i>	
Laser Fluid Velocity Detector .....	FRED H. SHIGEMOTO
A Method For Suppressing Or Attenu- ating Bending Motion Of Elastic Bodies. Control System .....	JAMES C. HOWARD
Protective Circuit Of The Spark Gap Type	Do.
Optical Machine Tool Alignment Indicator...	SALVADOR L. CAMACHO
	ALFRED G. BOISSEVAIN
	BYRON W. NELSON
Printed Circuit Soldering Aid .....	MILTON H. ROSS
Intruder Detection System .....	ROBERT D. LEE
Locomotion And Restraint Aid .....	HUBERT C. VYKUKAL
Electrode Construction .....	RICHARD M. WESTBROOK
	JOSEPH J. ZUCCARO
Satellite Communications System .....	GEORGE W. CLEMENS, JR.
	ALFRED C. MASCY
Thermoelectric Radiometer Utilizing Polymer Film.	BENJAMIN H. BEAM
Inertia Diaphragm Pressure Transducer...	LARRY D. RUSSELL
	HENRY L. B. SEEGMILLER
<i>Goddard Space Flight Center:</i>	
A Programmable Telemetry System .....	MARVIN S. MAXWELL
	PAUL M. FEINBERG
	EUGENE A. CZARCINSKI
	JOSEPH R. SILVERMAN
	JOHN G. LESKO, JR.
Charge Current Controller For Sealed Electro-Chemical Cells With Control Electrodes.	NELSON POTTER
Marine Engineering Laboratory .....	KENNETH SIZEMORE
Direct Current Motor With Stationary Armature And Field .....	FLOYD FORD
Automatic Formation Cycler And Con- troller For Electrochemical Cells.	PIOTR P. M. LIWSKI
	PHILIP A. STUDOR
	FLOYD E. FORD
	THOMAS J. HENNIGAN
	NELSON POTTER
	KENNETH SIZEMORE

Contribution	Inventor (s)
<i>Goddard Space Flight Center—Contd.</i>	
Attitude Control System -----	CLARENCE CANTOR FRANK A. VOLPE
Segmented Superconducting Magnet For A Broad Band Traveling Wave Maser.	JOHN J. DELUCA LARRY E. ROUZER
Use Of Unilluminated Solar Cells As Shunt Diodes For A Solar Array.	ANTHONY J. BARBERA
Trap For Preventing Diffusion Pump Backstreaming.	HAROLD SHAPIRO
Satellite Communication System And Method.	ROBERT J. DARCEY
Cosmic Dust Sensor -----	OTTO E. BERG
Electromagnetic Polarization Systems And Methods.	RALPH E. TAYLOR
Annular Slit Colloid Thruster -----	KENNETH W. STARK WILLIAM A. BURTON ALLAN SHERMAN
<i>Langley Research Center:</i>	
Spray Gun Nozzle -----	OCE W. JOHNSON
Maksutov Spectrograph -----	GALE A. HARVEY
Ablation Compound Molding -----	CHARLES B. KING ROBERT T. SWANN MARTIN J. MENGES
Rate Augmented Digital-To-Analog Converter.	SHELDON KOPELSON
Equipotential Space Suit -----	DONALD E. BARTHLOME
Leak Detector -----	MILES L. LOCKARD
Thermopile Vacuum Gage Tube Simulator.	PAUL R. YEAGER
<i>Lewis Research Center:</i>	
Corrosion Resistant Beryllium -----	PATRICIA M. O'DONNELL
Fluid Jet Amplifier -----	WILLIAM S. GRIFFIN
Heat Activated Cell -----	JACOB GREENBERG THOMAS E. SEITZ
Heat Activated Cell -----	JACOB GREENBERG
<i>George C. Marshall Space Flight Center:</i>	
Shielded Flat Cable And Method Of Making The Same.	WILHELM ANGELE BOBBY W. KENNEDY
Method For Coating Through-Holes ----	GEORGE L. FILIP
Method Of Making Homogeneous Ma- terials In A Zero Gravity Environment.	HANS F. WUENSCHER
Filter System For Control Of Outgas Contamination In Vacuum.	BOBBY W. KENNEDY
Cascaded Solid-State Image Amplifier Panels.	ROBERT L. BROWN, SR.
Fine Adjustment Mount -----	WALTER E. KASPARACK
Method And Apparatus Of Simulating Zero Gravity.	HELMUT G. LACKNER

Space Act Section 306 Awards Summary  
(January 1-June 30, 1969)

Types	Number of Contributions	Number of Awardees	Amount of Awards
Invention and Contribution Awards in Excess of \$50 Minimum -----	40	61	\$19,200
Minimum \$50 Awards for Patentable Inventions -----	56	80	4,000
Minimum \$25 Awards for Tech Briefs --	429	721	18,025
Totals -----	525	862	\$41,225

Appendix K

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NASA's Contract Adjustment Board

(June 30, 1969)

Chairman	-----	E. M. SHAFER
Members	-----	ERNEST W. BRACKETT
		FRANK J. SULLIVAN
		MELVYN SAVAGE
		WILLIAM E. STUCKMEYER
Counsel to Board	-----	DANIEL M. ARONS

Appendix L

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NASA's Board of Contract Appeals

(June 30, 1969)

Chairman	ERNEST W. BRACKETT
Vice Chairman	MATTHEW J. MCCARTIN
Members	WOLF HABER
	DONALD W. FRENZEN
	DANIEL M. ARONS
	JOHN B. FARMAKIDES
	(Vacancy)
Recorder	(MRS.) EVELYN M. KIRBY

## Appendix M

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### Educational Publications and Motion Pictures

(January 1–June 30, 1969)

NASA released these new publications during the first half of the year. They were distributed by NASA and sold by the Superintendent of Documents, U.S. Government Printing Office. Current offerings are listed in the booklet *NASA Educational Publications*, available from NASA, Code FGC-1, Washington, D.C. 20546.

#### Booklets

*This Is NASA.*—Brief description of the Agency's past, present, and future programs. (EP-22, 20 pp.)

*Space Resources for Teachers: Biology.*—A curriculum project prepared by the Lawrence Hall of Science, University of California (Berkeley). Includes suggestions for classroom activities and laboratory experiments. (EP-50, 236 pp., \$2.75 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

*Apollo 8—Man Around the Moon.*—The first manned lunar orbiting flight by Astronauts Borman, Lovell, and Anders in December 1968 recorded in full color. (EP-66, 24 pp.)

*Code Name "Spider": The Flight of Apollo 9.*—First flight of the Lunar Module in space described. (EP-68, 16 pages of color photographs.)

*Mission Report/Apollo 10.*—An account of the final full-dress rehearsal for the first manned lunar landing. (EP-70, 12 pp., illus. in color.)

*"In This Decade" . . . Mission To The Moon.*—An outline of the complex steps leading to a manned lunar landing in this decade. NASA's aerospace research and development is described. (EP-71, 48 pp., color illus.)

*A Universe to Explore.*—Space sciences source book for junior high school teachers prepared as a cooperative project of NASA and the National Science Teachers Association. (NSTA, 139 pp.,

\$4 from the National Science Teachers Association, 1201 16th Street, NW., Washington, D.C. 20036.)

### NASA Facts

*Biosatellite II.*—Outline of the unamanned space flight experiment of September 1967 to study the effects of weightlessness, radiation, and circadian rhythm on living things. (NF-3, 12 pp., color illus.)

### Motion Pictures\*

NASA also completed and released four new informational-educational films. These may be borrowed, without charge other than return mailing and insurance costs, from Media Development Division, Code FAD-2, National Aeronautics and Space Administration, Washington, D.C. 20546, or from any NASA Center. (Other films are listed in a brochure supplied from the same addresses.)

*Apollo 9: The Space Duet of Spider and Gumdrops* (HQ-189).—color, 28½ min., 16 mm. Documentary of the Apollo 9 mission—the first earth-orbital rendezvous and docking of the Command Module (Gumdrops) and the Lunar Module (Spider).

*Apollo 10: Green Light for a Lunar Landing* (HQ-190).—color, 28½ min., 16 mm. This film highlights the mission which took men within nine miles of the lunar surface and paved the way for the first manned lunar landing.

*A New Look At An Old Planet* (HQ-178).—color, 25 min., 16 mm. How space research and development helps solve some of the problems of man on earth: space-related techniques for discovering such things as mineral deposits, schools of fish, and diseased crops; the use of aerospace technology to improve worldwide communications, weather forecasting, and navigation.

*Seas of Infinity* (HQa-135-1969).—color, 14½ min., 16 mm. Reviews the planning, development, launching, and operation of the Orbiting Astronomical Observatory carrying telescopes to study the solar system and the stars beyond it.

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\*NASA loaned 50,000 film prints for non-TV showings to about 4 million people. Prints of NASA films on the Apollo Program were used in 50 cities in the President's Youth Opportunity Program. The Central Film Depository released 59,485 feet of motion picture footage—an increase of 65 percent over the previous period. An additional 322,017 feet of stock footage was catalogued and stored for a total of 9,224,368 feet.

## Appendix N

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### TECHNICAL PUBLICATIONS

(January 1–June 30, 1969)

The following special publications, among those issued during the report period by NASA's Scientific and Technical Information Division, are sold by the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, D.C. 20402, or by the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Springfield, Va. 22151.

*Thermal Radiation Heat Transfer, Vol. II: "Radiation Exchange Between Surfaces and in Enclosures"* (John R. Howell and Robert Siegel).—This volume treats the exchange of energy between surfaces and in enclosures. NASA SP-164, June 1969. 285 pp. GPO, \$1.50.

*Relay Program Final Report*.—Sequel to "Relay I Final Report" (NASA SP-76), summarizes the operations of the Relay II satellite. NASA SP-151. April 1969. 365 pp. GPO, \$3.25.

*Significant Achievements in Space Science, 1967*.—A summary. NASA SP-167. May 1969. 558 pp. GPO, \$2.50.

*Earth Photographs from Gemini VI through XII*.—A collection of color pictures. NASA SP-171. June 1969. 327 pp. GPO, \$8.00.

*Batteries For Space Power Systems* (Paul Bauer).—A monograph written under contract for OART. NASA SP-172. February 1969. 306 pp. GPO, \$1.50.

*NASA Science and Technology Advisory Committee For Manned Space Flight: Proceedings of the Winter Study on Uses of Manned Space Flight, 1975–1985. Volume I: Proceedings*.—Results of a conference on the application of manned space flight to scientific and technological objectives. NASA SP-196. April 1969. Vols. I and II. 40 pp. CFSTI, \$3.00.

- Lunar Orbiter I Preliminary Results: Lunar Terrain Assessment and Selenodesy, Micrometeoroid, and Radiation Measurements* (J. Kenrick Hughes and Gerald W. Brewer).—NASA SP-197. June 1969. 141 pp. CFSTI, \$3.00.
- EXAMETNET Data Report Series Annual Report, 1966*.—EXAMETNET data acquired by each participant for 1966. NASA SP-175. January 1969. 194 pp. CFSTI, \$3.00.
- EXAMETNET Data Report Series Annual Report, 1967*.—NASA SP-176. April 1969. 184 pp. CFSTI, \$3.00.
- Proceedings of the Working Group on Extraterrestrial Resources*.—Technical papers presented at the Sixth Annual Meeting of this Working Group. NASA SP-177. March 1969. 273 pp. GPO, \$2.50.
- The Book Of Mars* (Samuel Glasstone).—Data on Mars for scientists and intelligent laymen. NASA SP-179. February 1969. 315 pp. GPO, \$5.25.
- Lectures in High-Energy Astrophysics* (H. Ogelman and J. R. Wayland).—An expanded and edited version of notes for an introductory graduate level course in high-energy astrophysics. NASA SP-199. June 1969. 165 pp. CFSTI, \$3.00.
- Models of Trapped Radiation Environment, Vol. V: "Inner Belt Protons"* (James P. Lavine and James I. Vette).—Updates and supersedes Volume I. NASA SP-3024. June 1969. 56 pp. CFSTI, \$3.00.
- Charts for Interpolation of Local Skin Friction from Experimental Turbulent Velocity Profiles* (Jerry M. Allen and Dorothy H. Tudor).—Charts calculated from the Fenter-Stalmach law of the wall. NASA SP-3048. May 1969. 37 pp. CFSTI, \$3.00.
- Real-Gas Effects in Critical Flow Through Nozzles and Thermodynamic Properties of Nitrogen and Helium at Pressures to  $300 \times 10^5$  Newtons per Square Meter (Approx. 300 ATM)* (Robert C. Johnson).—A critical-flow factor for calculating the mass-flow rate of gaseous nitrogen and helium through critical-flow nozzles and the FORTRAN IV subroutines used to calculate the results. NASA SP-3046. January 1969. 201 pp. CFSTI, \$3.00.
- Astronautics and Aeronautics, 1967: Chronology on Science, Technology, and Policy*.—A chronology of events and statements. NASA SP-4008. May 1969. 487 pp. GPO, \$2.25.

*Cumulative Index to NASA Tech Briefs, January-December 1968.*

—Tech Briefs are short announcements of innovations and developments potentially applicable to problems outside and within the aerospace industry. NASA SP-5021(08). April 1969. 151 pp. CFSTI, \$3.00.

*The Metallurgy, Behavior, and Application of the 18% Nickel Maraging Steels* (A. M. Hall and C. J. Slunder).—This reports results of a survey of users and manufacturers of maraging steels. NASA SP-5051. January 1969. 137 pp. GPO, \$1.50.

*Joining Ceramics and Graphite to Other Materials* (H. E. Pattee, R. M. Evans, and R. E. Monroe).—A review of this subject. NASA SP-5052. January 1969. 84 pp. GPO, \$1.00.

*NASA Contributions to Bioinstrumentation Systems* (Gershon Weltman, Moshe Klagsbrun, Donald Ukkestad, and Ben Ettelson).—Advances in bioinstrumentation devices and techniques in the Mercury and Gemini flights. NASA SP-5054. January 1969. 97 pp. GPO, \$1.00.

*NASA Contributions to Fluid Film Lubrication* (H. C. Rippel, Otto Decker, and Z. Zudans).—Reviews advances in fluid film lubrication. NASA SP-5058. June 1969. 196 pp. GPO, \$2.00.

*Teleoperator Controls* (William R. Corliss and Edwin G. Johnsen).—An AEC-NASA survey on teleoperator control technology. NASA SP-5070. March 1969. 162 pp. CFSTI, \$3.00.

*Industrial Heating Advances: Applications to 5800°F* (A. F. Leatherman and D. E. Stutz).—Advances in the use of induction heating at higher temperatures. NASA SP-5071. April 1969. 41 pp. GPO, 30 cents.

*Air Pollution-Monitoring Instrumentation* (Alvin Lieberman and Peter Schipma).—This survey describes 32 instruments and techniques used in transferring air pollution monitoring technology developed in aerospace research to industry. NASA SP-5072. May 1969. 74 pp. GPO, 40 cents.

*Pavement Grooving and Traction Studies*.—Proceedings of a conference on the effects of pavement grooving on aircraft performance and operational problems. NASA SP-5073. March 1969. 512 pp. CFSTI, \$3.00.

*Weather Satellite Picture Receiving Stations* (Charles H. Vermillion).—A revised and updated version of NASA SP-5079, *Constructing Inexpensive Automatic Picture-Transmission Ground*

*Stations*, which described how to build a receiving station to be used with weather satellites. NASA SP-5080. June 1969. 95 pp. CFSTI, \$3.00.

*NASA Scientific and Technical Reports for 1968: A Selected Listing*.—A list of publications and journal articles announced during 1968 in *Scientific and Technical Aerospace Reports* (STAR). NASA SP-7033. June 1969. 445 pp. GPO, \$4.00.

*Buckling of Thin-Walled Circular Cylinders* (Revised August 1968).—Current practices for predicting buckling of uniform stiffened and unstiffened circular cylindrical shells under various types of static loading. NASA SP-8007. April 1969. 49 pp. CFSTI, \$3.00.

*Propellant Slosh Loads*.—This monograph is concerned primarily with the loads on a tank during lateral and longitudinal sloshing and with baffle pressure loads due to sloshing. NASA SP-8009. January 1969. 25 pp. CFSTI, \$3.00.

*Models of Venus Atmosphere (1968)*. A set of engineering models of the Venus atmosphere to serve design and planning requirements until more definitive knowledge evolves. NASA SP-8011. March 1969. 31 pp. CFSTI, \$3.00.

*Natural Vibration Model Analysis*.—The determination and evaluation of natural vibration modal data for space vehicle structure. NASA SP-8012. April 1969. 31 pp. CFSTI, \$3.00.

*Entry Thermal Protection*.—Steps or precautions which should be taken to ensure an adequate design of a thermal protection system. NASA SP-8014. February 1969. 33 pp. CFSTI, \$3.00.

*Guidance and Navigation for Entry Vehicles*.—A monograph on the atmospheric entry phase of flight for vehicles with maximum lift-drag ratios of less than 1.5. NASA SP-8015. March 1969. 43 pp. CFSTI, \$3.00.

*Buckling of Thin-Walled Truncated Cones*.—Practices for predicting buckling of uniform stiffened and unstiffened circular conical shells under various types of static loading; suggested procedures to yield conservative estimates of static buckling loads. NASA SP-8019. June 1969. 25 pp. CFSTI, \$3.00.

## Appendix O

### Major NASA Launches

(January 1-June 30, 1969)

Name, date launched, mission	Vehicle	Site <sup>1</sup>	Results
OSO-V (OSO-F), January 22 -- Orbiting Solar Observatory designed to study the sun and its influence in inter- planetary space near the earth.	Delta -----	ETR ---	The 641-pound Observatory was successfully placed into a 350- mile circular orbit. Its ex- periments were operating as planned.
ISIS-I, January 30 ----- Canadian-American Inter- national Satellite for Ion- ospheric Studies planned to help scientists understand the upper ionosphere through radio soundings and direct measurements of the medium surrounding the spacecraft.	Delta -----	WTR---	The 532-pound spheroidal satellite, built by Canada, was launched by NASA into a near polar, highly elliptical orbit (apogee 2,200 miles; perigee 350 miles). Its radio soundings were provid- ing ionospheric data by remote sensing.
INTELSAT III (F-3), Febru- ary 5. A 1200-circuit satellite launched as part of a global commercial communications satellite system.	Delta -----	ETR---	Spacecraft launched into a trans- fer orbit by NASA for ComSat and positioned into a synchro- nous orbit by ComSat. Perform- ing satisfactorily over the In- dian Ocean.
Mariner VI, February 24 ----- One of two satellites to study the surface and at- mosphere of Mars, to return TV pictures of the surface, and to develop technology for later Martian missions.	Atlas-Centaur --	ETR ---	Since its launch and mid-course correction the spacecraft has operated as designed. (Made an equatorial pass of the planet on July 31—an estimated 2,165 miles away.)
ESSA IX (TOS-G), Febru- ary 26. To serve as the primary stored-data satellite in the operational meteorological system providing global cloud pictures for weather forecasting and warnings.	Delta -----	ETR ---	Ninth and last of the satellites in the TOS series, placed in a nearly polar, sun-synchronous orbit about 900 miles above the earth. Views the weather once every 24 hours, photo- graphing a given area at the same local time each day.

<sup>1</sup> See footnote at end of table.

## Major NASA Launches—Continued

(January 1–June 30, 1969)

Name, date launched, mission	Vehicle	Site <sup>1</sup>	Results
Apollo 9 (AS-504), March 3 --- To evaluate the performance of the complete Apollo system in a manned earth-orbiting flight.	Saturn V -----	ETR ---	Ten days in earth orbit and recovered in the Atlantic Ocean. First manned flight of the Lunar Module. Astronauts McDivitt, Scott, and Schweickart successfully demonstrated CSM-LM rendezvous. Schweickart carried out 38-minute EVA.
Mariner VII, March 27 ----- Spacecraft with equipment identical to Mariner VI, but to flyby the Southern polar region of Mars.	Atlas-Centaur --	ETR ---	Supplied photographs of and data on the planet's Southern polar cap and surrounding areas when it came within about 2,071 miles of the surface on August 5.
Nimbus III (Nimbus B2), April 14. To carry experiments leading to reliable long-range weather forecasting. (Replaces Nimbus B destroyed at launch on May 18, 1968.)	Thorad-Agena D	WTR---	In a nearly polar orbit 690 miles above the earth. Army's geodetic satellite, SECOR, a secondary payload placed into a separate 600-mile circular orbit. Nimbus and SECOR operating as planned. Nimbus achieved the first sounding of the atmosphere from a satellite.
Apollo 10 (AS-505) May 18 --- Manned mission development flight about the moon to evaluate Lunar Module performance in the cislunar and lunar environments.	Saturn V -----	ETR ---	Astronauts Stafford, Cernan, and Young conducted a nearly perfect dress rehearsal simulating the lunar landing mission, except for the actual landing and surface activities. Also photographed landing sites and "scientific targets". First mission during which the complete Apollo spacecraft operated around the moon. The Lunar Module (on its second manned flight) descended to within 9 miles of the lunar surface. Spacecraft recovered in the Pacific May 26.
INTELSAT III (F-4), May 21 -- Orbited by NASA—on a reimbursable basis for ComSat—as part of a worldwide commercial communications satellite system.	Delta -----	ETR ---	Operating in a synchronous orbit over the Pacific Ocean.
OGO-VI (OGO-F), June 5 ---- Last of the Orbiting Geophysical Observatories carrying many coordinated experiments to investigate the earth's upper atmosphere	Thorad-Agena--	WTR---	Spacecraft in a polar orbit between 245 and 680 miles. The 25 experiments on board were operated successfully.

<sup>1</sup> See footnote at end of table.

Major NASA Launches—Continued

(January 1–June 30, 1969)

Name, date launched, mission	Vehicle	Site <sup>1</sup>	Results
OGO-VI (OGO-F), June 5— Cont. and ionosphere, auroral re- gions surrounding the poles, and trapped radiation.			
Explorer XLI (IMP-G), June 21. An Interplanetary Monitor- ing Platform designed to study solar plasma, mag- netic fields, and cosmic rays.	Delta -----	WTR---	Launched into a near-polar earth orbit (apogee 110,000 miles; perigee 215 miles.) The ex- periments aboard the 174-pound spacecraft were operating as designed.
Biosatellite III (Biosatellite D), June 28. Satellite designed to use the weightless environment of space as a research tool to help answer basic ques- tions about mental, emo- tional, and physiological processes in a subhuman primate.	Delta -----	ETR ---	Launched into earth orbit at an altitude of about 200 miles. Spacecraft systems performed as expected, and data on the condition of the monkey were recorded at all stations.

<sup>1</sup> ETR—Eastern Test Range, Cape Kennedy, Fla.  
WTR—Western Test Range, Point Arguello, Calif.

## Appendix P

### NASA Launch Vehicles

Vehicle	Stages	Payload in pounds			Principle use
		345-mile orbit	Escape	Mars/Venus	
Scout -----	4	320 -----			Launching small scientific satellites, reentry experiments, and probes (Explorers XXXIX and XL, SERT ion engine, ESRO 1A, San Marco B, Reentry F, RAM C, French FR-1).
Thrust Augmented Delta (TAD).	3	2,000	525	500	Launching scientific meteorological, communications, and bioscience satellites, and lunar and planetary probes (Pioneer VI, TIROS-M, TIROS Operational Satellites OT-3 and OT-2, Syncom III, Commercial communications satellites Early Bird I and INTELSAT I, II, III, Radioastronomy Explorer, Biosatellites I-III, International Satellite for Ionospheric Studies-ISIS.)
Thrust Augmented Thor-Agena (TAT).	2	2,200 -----			Launching geophysics, astronomy, and applications satellites (OGO-III, -IV, and -VI, Nimbus II and III, and SERT II).
Atlas-Centaur -----	2½	9,900	2,600	1,600	Launching medium-weight unmanned spacecraft (Mariner, ATS, OAO, and Pioneer).
Saturn IB -----	2	40,000 <sup>1</sup> -----			Launching Project Apollo and Apollo Applications CSM.
Saturn V -----	3	270,000 <sup>1</sup>	100,000	80,000	Launching Apollo spacecraft, AAP orbital workshop, experiments, and ATM.

<sup>1</sup> For 100 nautical mile-orbit.

## Appendix Q

### Institutions Currently Participating in NASA's Predoctoral Training Program

(June 30, 1969)

Adelphi University	Kansas, University of <sup>1</sup>
Alabama, University of	Kent State University
Alaska, University of	Kentucky, University of
Alfred University	Lehigh University
Arizona State University	Louisiana State University
Arizona, University of	Louisville, University of
Arkansas, University of	Lowell Technological Institute
Auburn University	Maine, University of
Baylor University	Marquette University
Boston College	Maryland, University of
Boston University	Massachusetts Institute of Technology
Brandels University	Massachusetts, University of
Brigham Young University	Miami, University of <sup>5</sup>
Brooklyn, Polytechnic Institute of	Michigan State University
Brown University	Michigan Technological University
California Institute of Technology	Michigan, University of
California, University of, at Berkeley	Minnesota, University of
California, University of, at Los Angeles	Mississippi State University
California, University of, at Riverside	Mississippi, University of
California, University of, at San Diego	Missouri, University of
California, University of, at Santa Barbara	Missouri, University of, at Rolla
Carnegie-Mellon University	Montana State University
Case Western Reserve University	Montana, University of
Catholic University of America	Nebraska, University of
Chicago, University of	Nevada, University of
Cincinnati, University of	New Hampshire, University of
Clark University	New Mexico State University
Clarkson College of Technology	New Mexico, University of
Clemson University	New York, The City University of
Colorado School of Mines	New York, State University of, at Buffalo
Colorado State University	New York, State University of,
Colorado, University of	at Stony Brook
Columbia University	New York University
Connecticut, University of	North Carolina State
Cornell University <sup>1</sup>	of the University of North Carolina <sup>4</sup>
Dartmouth College	North Carolina, University of
Delaware, University of	North Dakota State University
Denver, University of	North Dakota, University of
Drexel Institute of Technology	Northeastern University
Duke University	Northwestern University
Duquesne University	Notre Dame, University of
Emory University	Ohio State University
Florida State University	Ohio University
Florida, University of	Oklahoma State University
Fordham University	Oklahoma, University of
George Washington University	Oregon State University
Georgetown University	Pennsylvania State University <sup>4</sup>
Georgia Institute of Technology <sup>1</sup>	Pennsylvania, University of
Georgia, University of	Pittsburgh, University of <sup>2</sup>
Hawaii, University of	Princeton University
Houston, University of	Purdue University <sup>1</sup>
Howard University	Rensselaer Polytechnic Institute
Idaho, University of	Rhode Island, University of
Illinois Institute of Technology	Rice University
Illinois, University of	Rochester, University of
Indiana University	Rutgers—The State University
Iowa State University	St. Louis University
Iowa, University of	South Carolina, University of
Johns Hopkins University	South Dakota, University of
Kansas State University	Southern California, University of <sup>2</sup>

See footnotes at end of table.

Southern Illinois University  
Southern Methodist University  
Southern Mississippi University of  
Stanford University 1 and 3  
Stevens Institute of Technology  
Syracuse University  
Temple University  
Tennessee, University of  
Texas A&M University  
Texas Christian University  
Texas Technological College  
Texas, University of  
Toledo, University of  
Tufts University  
Tulane University  
Utah State University  
Utah, University of

Vanderbilt University  
Vermont, University of  
Villanova University  
Virginia Polytechnic Institute  
Virginia, University of  
Washington State University  
Washington University (St. Louis)  
Washington, University of  
Wayne State University  
West Virginia University  
William and Mary, College of  
Wisconsin, University of  
Worcester Polytechnic Institute  
Wyoming, University of  
Yale University  
Yeshiva University

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<sup>1</sup> Institutions receiving training grants specifically for engineering systems design.

<sup>2</sup> Institutions receiving training grants specifically for administration and management.

<sup>3</sup> Institutions receiving training grants specifically for laser technology and aeronautics.

<sup>4</sup> Institutions receiving training grants specifically for vibrations and noise.

<sup>5</sup> Institutions receiving training grants specifically for international studies in science and technology.

